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The Future of Telecommunications is Open Source

Editorial

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Abstract: Papers in the September 2020 issue of the *Journal* include the NBN Futures Forum on the social and economic benefits of broadband for digital inclusion and telehealth, the benefits of submarine cables to South Pacific nations, 5G transmission, the economics of over-the-top media, energy efficient wireless sensor networks and a celebration of the life of Liz Fell, journalist and Distinguished Fellow of the Telecommunications Society of Australia (now the Telecommunications Association). This year, open source has moved into focus with the telecommunications industry, with open core systems and open radio access networks for 5G taking centre stage. The *Journal* welcomes contributions on telecommunications and the digital economy.

In This Issue

In this issue of the *Journal* papers cover the NBN Futures Forum on the social and economic benefits of broadband for digital inclusion and telehealth, the benefits of submarine cables to South Pacific nations, 5G transmission, the economics of over-the-top media, energy efficient wireless sensor networks, and a celebration of the life of Liz Fell, journalist and Distinguished Fellow of the Telecommunications Society of Australia (now the Telecommunications Association).

Elizabeth (Liz) Dyneley Fell, 1940-2020 provides a look back at the life and work of Liz Fell, a freelance journalist who was elected a Distinguished Fellow of the Telecommunication Society of Australia in 2003 for her notable and enduring contributions to Australian telecommunications.

Malcolm Turnbull — A Feisty Interview with the Shadow Minister is a historical reprint of Ms Fell's interview with the future Prime Minister who, as Minister for Communications in 2013-15, implemented the multi-technology mix redesign of the National Broadband Network.

The NBN Futures Forum: Social and Economic Benefits of Broadband for Digital Inclusion and Telehealth provides a summary of the fourth NBN Futures Forum, held online, on the

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theme of social and economic benefits of broadband, including discussion on digital inclusion and telehealth.

Pricing in Abundance: The Economics of the Manatua Cable presents the Manatua Cable Project, a submarine cable to the Cook Islands and discusses how the proposed wholesale pricing model facilitates increased retail competition.

A Compact 38 GHz millimeter Wave MIMO Antenna Array for 5G Mobile Systems presents the design of a microstrip antenna array.

Over-The-Top Media in Digital Economy and Society 5.0 presents a discussion on how over-the-top media distribution is changing business models in the Indonesian media market.

Energy-Efficient Topology to Enhance the Wireless Sensor Network Lifetime Using Connectivity Control presents a topology control approach to reduce energy utilisation.

The Future of Telecommunications is Open Source

The next step in the evolution of telecommunications has arrived and it is founded on open source and standards. The pace of change in the telecommunications landscape means that competition will be driven by the ability to rapidly develop and deploy solutions that meet customer needs. Legacy systems do not provide this flexibility. Global telecommunications equipment and systems vendors have embarked on open source projects that are community driven to ensure that products are extensible and customer needs are met.

5G has been a key driver of the change in approach taken by the global telecommunications suppliers. Projects including the Open Core Network (OCN), Open Networking Automation Platform (ONAP) (Ericsson) and Open Radio Access Network (O-RAN) have been launched to provide the foundations for ecosystems that are open, flexible and extensible.

The manoeuvring of projects, partnerships and race for acceptance is a central tenet for the global telecommunications equipment and systems vendors, lest they be seen to be isolated and not a participant in the development of the “accepted” ecosystems for 5G, cloud and core networks.

An example has been the adoption of the open source Linux Foundation Tungsten Fabric to provide networking and security across legacy, virtualised and containerised applications. Tungsten Fabric began as the Juniper Networks Open Contrail project.

The future for vendors lies with the provision of highly scalable solutions that embrace and support the underlying open source systems and an overlay ecosystem for application developers.

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Vendor platforms for orchestrating and automating the physical and virtual network devices and elements that utilise open source systems and interoperate with other vendor platforms and over-the-top applications through standardised interfaces are a major development that has now become the norm.

The *Journal*, Looking Forward

The *Journal* welcomes papers on telecommunications and the digital economy, including, theory, public policy, reviews and tutorials and case studies.

Technological change is happening at a rapid rate and consumers anticipate that governments and industry keep pace to ensure that the benefits can be fully utilised. The *Journal* is calling for papers on how new technologies will affect Australian telecommunications consumers.

The topics of *International Telecommunications Legislation and Regulations* and *International Mobile Cellular Regulation and Competition* are set to continue for some time, as the opportunity to attract papers from around the globe continues. We encourage papers that reflect on where the global telecommunications market is now, how it got to where it is, and what is going to happen next.

Papers are invited for upcoming issues. With your contributions, the *Journal* will continue to provide readers with exciting and informative papers covering a range of local and international topics. The Editorial Advisory Board also values input from our readership, so please let us know what themes you would like to see in the coming year.

All papers related to telecommunications and the digital economy are welcome and will be considered for publication after the double-blind peer-review process.

Mark A. Gregory

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Elizabeth (Liz) Dyneley Fell, 1940-2020

The distinguished journalist whose interviews covered major changes in the Australian telecommunications industry

Peter Gerrand
Editor-in-Chief of the *Telecommunications Journal of Australia* from 1994 to 2013

Abstract: Liz Fell (7 March 1940 to 13 August 2020), a freelance journalist, was elected a Distinguished Fellow of the Telecommunication Society of Australia in 2003 for her notable and enduring contributions to Australian telecommunications. Amongst others, she carried out brilliant interviews over twenty years (1994-2013) for the *Telecommunications Journal of Australia*. This article celebrates her notable contributions to Australian telecommunications, and includes references to two of her most famous interviews, with Malcolm Turnbull MP in 2011 and with the Hon. James (Jim) Spigelman AC, Chairman of the ABC, in 2013.

Keywords: Liz Fell, Australian telecommunications, Australian journalism, Telecommunications Journal of Australia, TelSoc.

Liz Fell's Contributions to Telecommunications and Journalism

Liz Fell (7 March 1940 to 13 August 2020), a freelance communications journalist, was elected a Distinguished Fellow of the Telecommunication Society of Australia in 2003 for her notable and enduring contributions to Australian telecommunications. Liz was the recipient of several other important awards for her journalism, including the George Munster Award for Freelance Journalism in 1986.

Her coverage of the telecommunications industry began in 1982 with contributions to *Communications Australia* and weekly broadcasts for ABC Radio Australia and ABC Radio National. She became a contributing editor of *International Communications Digest*, *Communications Update* and *Hub*, and a regular contributor of keynote interviews to *Australian Communications* and *CommsWorld*. At an international level, she was Australian

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correspondent for Television Business International and Cable and Satellite Asia, and contributed a monthly column to Asia Pacific Satellite.

Figure 1. Liz Fell in 2003 when elected a Distinguished Fellow of the Telecommunication Society of Australia ("New Distinguished Fellows", 2003)

Liz also worked as a part-time Lecturer and Senior Lecturer in a number of university Humanities and Arts faculties in Sydney, including teaching journalism and coordinating students' research theses for the Master in Journalism degree at the University of Technology Sydney. She also reported for the Federal Government on journalism education in Australian universities.

The Interviews

From 1994 to 2013 — twenty years! — she conducted interviews with more than sixty prominent leaders in Australian media and telecommunications for the *Telecommunications Journal of Australia* (TJA), the predecessor to TelSoc's current journal, the *Journal of Telecommunications and the Digital Economy*.

Industry stalwart Deena Shiff writes:

> Her series of interviews published in the *Telecommunications Journal of Australia*, strung end to end over two decades, tell the story of a telecommunications industry moving from monopoly to competition, to privatisation and back to monopoly.
>
> But they are brought to life by the people whom she interviewed. Really interviewed. With the advantage of deep knowledge patiently acquired.

To give you an idea of the range of her interviewees, they included: the Honourable James Spigelman AC, when newly appointed as chair of the ABC; Paul Twomey, when President and CEO of ICANN; Neil Tuckwell, when head of the industry regulator AUSTEL; Allan Horsley, when CEO of ATUG; and numerous other key players in telecommunications, such as John Almgren (JNA), Allan Asher (ACCAN), Barney Blundell (AAP), Hugh Bradlow (Telstra), Mara Bun (AConsumersA), John Burke (CIRCIT), Peter Coroneos (IIA), Greg Crew (ACIF), Terry Cutler†, Henry Ergas, Jim Holmes (Ovum), Anne Hurley (ACIF), Michael Malone (iiNet), Ian Noble (Google), Bill Page-Hannify† (Alcatel), Kevin Phillips (Telstra MobileNet), Johanna

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Plante (KPMG), Wally Rothwell (ATUG), Deena Shiff (Telstra), David Skellern (NICTA), Tony Shaw (ACA), David Spence (Unwired), Deanne Weir (Austar), and Larry Williams (AAPT). Amongst leading writers on Australian telecommunications, she interviewed Paul Budde, Peter Darling† and Jock Given; and amongst politicians, Malcolm Turnbull MP (Liberal) — see below — and Senator Kate Lundy (ALP).

Recollections by Her Colleagues

Liz Fell's long-time friend and colleague Trevor Barr, Emeritus Professor of Media Studies at Swinburne University, writes:

> Liz Fell possessed the healthy cynicism of a good journalist. She was always well prepared for her interviews, asked the questions that most readers would expect, and knew when further questioning of the subject was needed for clarification. She understood how important the notion of the public domain was in the Australian telecommunications industry during a time of major national public policy changes. The issues of benefits for end users were always foremost in her writing.

Blair Feenaghty, Executive Editor of the *Telecommunications Journal of Australia* (TJA) over 1994-2013, writes:

> Liz was a joy to work with. Her informed (and sometimes caustic) comments on who would make a good subject for her were extremely helpful. She was one of an old-fashioned group of journalists who believed that the interview should be about the subject, not about the interviewer.
>
> She was notable in that, unlike many, she did not terminate her interviews once she had achieved her own agenda. She allowed her subjects to fully speak their mind, believing that they might have something interesting to say which did not fit any preconceptions she might have brought to the interview.
>
> May her example live long after her.

As Liz's commissioning editor over those two decades, I noted that the research work which Liz undertook before each interview was prodigious. This gave her impressive command of the content of every interview, on topics ranging across the gamut of modern telecommunications, the media and the underlying economy.

Two of Her Best Interviews for TJA

Her command of her subject-matter is evident in all of her interviews. Blair, Trevor and I have chosen to draw attention to two of them.

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Her interview in 2011 with the Australian Shadow Minister for Telecommunications, Malcolm Turnbull MP, was notable for his combativeness (rare amongst her interviewees), born perhaps from their long acquaintance. In tribute to Liz, the *Journal* republishes in this issue as a companion article (Moorhead, 2020) that interview with the future Prime Minister who, as Minister for Communications in 2013-15, implemented the multi-technology mix redesign of the National Broadband Network we are familiar with today.

Her equally famous interview (Fell, 2013) in 2013 with the Hon. James (Jim) Spigelman AC, "From political activist to public intellectual", drew upon her own experience of social activism as well as her vast knowledge of the media, including many years working as a journalist for the organization he was now chairing, the ABC. This TJA interview was republished by the ABC and can still be found on the ABC website (About the ABC, 2013).

Those interested to learn more of Liz's whole life, including her earlier times as a university student, lecturer, ABC journalist and social activist, are referred to Wendy Bacon's obituary for Liz (Bacon, 2020).

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Malcolm Turnbull — A Feisty Interview with the Shadow Minister

Simon Moorhead
Ericsson Australia and New Zealand

Abstract: Liz Fell's interview in 2011 with the Australian Shadow Minister for Telecommunications, Malcolm Turnbull MP, was notable for his combativeness (rare amongst her interviewees). In tribute to both Ms Fell and Mr Turnbull, we republish that interview with the future Prime Minister who, as Minister for Communications in 2013-15, implemented the multi-technology mix redesign of the National Broadband Network.

Keywords: Liz Fell, Malcolm Turnbull, Australian telecommunications history, Australian journalism, Telecommunications Journal of Australia.

Introduction

Liz Fell's interview with Malcolm Turnbull on behalf of the *Telecommunications Journal of Australia* (TJA), took place in early January 2011 (Fell, 2011). This was around six months after the Labor Party had retained government following an Australian federal election.

Readers may remember that Julia Gillard challenged Kevin Rudd on 24 June 2010 and replaced him as the Labor Prime Minister. She received agreement from the Governor General to hold a snap election on 21 August 2010. Gillard was able to hold onto Government for Labor by obtaining crossbench support from four MPs, namely one Green and three Independents, thereby denying the Liberal-National Coalition, with Tony Abbott as leader of the Liberal Party, the right to govern for another three years. The independents quoted Labor's National Broadband Network, which Tony Abbott had strongly opposed, as being the key policy reason for their supporting Gillard's minority government (Gerrand, 2010).

In Turnbull's recent memoir, *A Bigger Picture* (Turnbull, 2020), he relates how in 2010 Mr Abbott as Opposition Leader asked him to be Shadow Minister for Broadband and Communications to create a credible alternative broadband policy. Turnbull had considerable prior experience as an investment banker in telecommunications and software companies,

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including as chairman of OzEmail, which became Australia's largest internet service provider, before it was sold to WorldCom in 1997.

Turnbull was only six months into serving as Shadow Communications Minister when Fell interviewed him for TJA. Turnbull had strong views on the path to success that NBN should take and it was not the path that Stephen Conroy had set in motion as Rudd's Broadband Minister.

Fell had a number of issues she wanted to cover in the limited time available for the interview. Fell interrupts Turnbull several times and he responds with "Liz you don't let me finish". Towards the end of the interview, Turnbull's media adviser, Jon Dart, says "We'll have to wrap this up", but Fell points out that Turnbull was 30 minutes late for a 60-minute interview. Turnbull graciously agrees to more questions and Fell (true to form) hits him with some difficult ones, including about Wikileaks, the convergence of media regulation and the structural separation of Telstra.

Fell finishes with the question:

> *"You've said the NBN is 'a bit of a dream' and 'appeals to dreamers'. Do you still hold to these statements?"*

Turnbull answers:

> *"Well, I think whenever politicians talk about nation-building infrastructure, you want to start reaching for your wallet. I'm not suggesting that there isn't a role for infrastructure that helps build a nation – all infrastructure does that – but all too often they use that term to justify projects that haven't been well thought through.*
>
> *Again, Liz, I'm not against it. I'm madly in favour of broadband, indeed passionately in favour of it. My concern is simply cost-effectiveness. If we could deliver, for example, ADSL2+ speeds or better across Australia for a fraction of the NBN cost, why wouldn't we do that and then see where technology went?*
>
> *I mean Conroy talks about this on the basis of what demand may be in 30 years' time. We have no idea. Cast your mind back – 30 years was 1981 for goodness sake!"*

Turnbull went on to be the Minister for Communications in the Abbott government in 2013, and later ousted Abbott to become Prime Minister in 2015. He presided over the current multi-technology mix redesign for the NBN, which he foreshadowed to Fell in this interview back in 2011.

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The Historic Paper

INTERVIEW

MALCOLM TURNBULL

A FEISTY INTERVIEW WITH THE SHADOW MINISTER

Liz Fell

The Hon Malcolm Turnbull was first elected to the Federal House of Representatives in 2004 as the Liberal Party member for the Sydney electorate of Wentworth and became the Shadow Minister for Communications and Broadband in September 2010.

During the Howard government, Turnbull was first appointed as Parliamentary Secretary to the Prime Minister (Jan 06 - Jan 07) and Cabinet Minister for Environment and Water Resources (Jan 07 - Dec 07). When Labor took government after the 2007 election, Turnbull became Shadow Treasurer (Dec 07 - Sept 08), Leader of the Opposition and Parliamentary Leader of the Liberal Party (Sept 08 - Dec 09) and, after the 2010 election, Shadow Minister for Communications and Broadband.

Before entering Federal parliament, Turnbull practised as a journalist (1975 - 80), barrister and general counsel for Consolidated Press Holdings Ltd (1980s), and an investment banker with Whitlam Turnbull and Co Ltd. (1987 - 1990), Turnbull & Partners Ltd (1990 - 97), Goldman Sachs Australia (1997 - 2001) and Goldman Sachs and Co. (1998 - 2001).

After graduating from the University of Sydney with a BA (1977) LLB (1978), Turnbull won a Rhodes scholarship enabling him to complete a BCL (Hons) degree at the University of Oxford.

Freelance journalist, Liz Fell conducted this interview with Turnbull for the TJA in mid-January at his Edgecliff office in the electorate of Wentworth. Turnbull's media adviser, Jon Dart, was also present during the interview, which has been edited to cut back on its length.

Malcolm Turnbull

TJA: Before addressing your main concern, the National Broadband Network, can we touch on your long-term interest in communications technology and start-up companies, including your early adoption of web-based media? One colleague from your days as a legal student remembers your relationship with a pager that went off during law lectures when you were also working as a journalist. Is that correct?

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Turnbull: Yes, that's right. I was working for Channel Nine, 2SM and the Nation Review – all three of them – and I can't remember who gave me the pager. I think it might have belonged to 2SM.

Turnbull: (to Jon Dart) You don't know what a pager is?

Dart: No.

Turnbull: A pager is a little device about that long and square (he demonstrates) and they could ring a number and that caused it to go beep, beep, beep. All it did was to tell you to go and ring home or ring the office. You just got a beep, there was no message.

TJA: You clearly enjoyed being a journalist! I admired one of the apocryphal stories: that you secured an interview with Rupert Murdoch by dialling each extension of the New York Post switchboard until he answered the phone!

Turnbull: That's right. I just worked through what I thought were the extensions until finally he picked up the phone. That was the first time I met him.

TJA: Then in 1997, when you were Chairman of the Internet service provider, OzEmail Ltd, I found you excited at the quality of a three-hour conference call with the US you had just had over the net.

Turnbull: Well, if OzEmail wasn't the first, it was one of the very first commercial Internet telephony businesses.

TJA: In the world?

Turnbull: Yes, in the world. OzEmail Interline was a technology almost entirely developed by Rick Spielrein from Melbourne – Rick and Sean (Howard). There were some other people involved, but Rick was the key guy. The way it worked, you used your telephone to dial into a node, say, in Sydney, which then routed the call over the Internet to a node, say, in New York, which then made a call to the number you wanted.

TJA: So there you were again, interested in technology. Is it fair to say you developed a certain amount of expertise in this area over the years?

Turnbull: I think it would be wrong to say I've got expertise. I'm not an engineer. I've got experience.

TJA: And as an experienced banker you invested in and/or advised a number of software and telco companies after OzEmail, including Unwired, for instance?

Turnbull: Yes.

TJA: Watching you on the stage last year at an election forum you chaired to argue against the Government's mandatory filtering policy, you were almost 'glued' to your iPad.

Turnbull: The iPad basically in large measure has replaced paper in my life. The great functionality for me is the fact that it's so good for reading documents. You spend so much time reading reports, and papers, you know.

TJA: Didn't you have a Kindle at one stage?

Turnbull: Yes, it's been said that now I've got the iPad, my Kindle is like the little....(To Dart: What's the little...?)

Dart: Woody, the cowboy.

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Turnbull: Yes, Woody the cowboy in Toy Stories, the abandoned toy. (laughter)

TJA: Looking at your website with its iPhone App and all the social media you use to communicate including Twitter, Flickr, Facebook, MySpace, and YouTube, you must lead the political pack in the management of your 'brand' or 'reputation'. You certainly stimulate a lot of discussion about your policies which is not so evident with the Government.

Turnbull: Yes, well I think the big failing, particularly in the context of the NBN, is that the Government has been focused on the hardware side and really what they ought to be doing is more to promote the use of technology. You know, there's very little, for example, in terms of e-government and making government more efficient and accountable.

TJA: In the last issue of the TJA, Senator Kate Lundy talked about her activities to promote e-government ... but what do you suggest?

Turnbull: Well, I've been arguing this for a very long time, for five or six years at least. I think a very simple thing that governments can do, and this is a very basic thing, is that the government should provide every Australia with a free electronic pigeonhole.

TJA: Would this serve as an ID of some sort?

Turnbull: No, what it would be is a unique address, essentially like an electronic folder, an electronic mailbox. I call it a pigeonhole because I think you would want to limit its functionality so that it could only receive material from Government, and maybe from financial institutions.

TJA: Not friends?

Turnbull: No, this is something worth discussing, but my simple point is this. If you try and manage electronic databases as I do, one of the problems you have is that people change their email addresses, and they change them as often, if not more often, than their physical addresses. The cost of electronic communication is, you know, just a tiny percentage of snail mail etcetera, and one of the problems governments have is that they don't have a lot of people's email addresses.

TJA: Maybe some people don't want governments to have their address?

Turnbull: What I'm saying is that if you offer everybody the opportunity to be, say, malcolm.Turnbull.dateofbirth@australia.gov.au or whatever. The government is then in a position to say, 'We'll give you that unlimited storage basically and we will then ensure that all government communication comes to you electronically.' Now the good thing about that is...

TJA: What....

Turnbull: Let me go on...

TJA: Yes, sure, briefly...

Turnbull: Briefly. Who is interviewing whom? Am I interviewing you?

TJA: No, go on please...

Turnbull: The virtue is that you not only have a huge saving in communications costs but it means that people know there will always be, in effect, an electronic filing cabinet with all of their correspondence from the taxation department, and all of their correspondence, say, with respect to their superannuation.

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TJA: Would the private sector play a role?

Turnbull: Well, this is the thing. I mean you would certainly say that the electronic pigeonhole would be designed to receive communications from governments, you know, federal, state, local. One of the big problems is people losing track of their superannuation entitlements because they have changed jobs, so it would be commonsense to make it available to financial institutions. Now how far do you take it? Maybe you don't limit it, but that electronic pigeonhole would provide a permanent electronic record of communications and it would mean that you wouldn't have the risk of things going astray.

TJA: Will governments gather a lot of information about citizens?

Turnbull: No, they would only know what they had sent you. That's the argument. You see you could design a. .. (Turnbull walks to a white board at the other end of the room.)

TJA: We are not including visuals, and my recorder has to pick up your voice way down there so, please, could you come back?

Dart: (Laughing) This is why we need the GPS...

Turnbull: Alright, alright .The point is that there is literally no technical barrier to doing that at all, but it obviously would take a long time for people to get used to it.

TJA: Moving to the NBN, Prime Minister Gillard claims that your leader, Tony Abbott, told you to 'do anything you can to destroy it'. Is that correct?

Turnbull: No, no. What Abbott was referring to there was about attacking the argument. I've got no interest in destroying the NBN, or anything for that matter. My aim is simply to ensure, as far as I can, that we have the most cost-effective approach to solving the problem.

TJA: Do you agree with the concept of the NBN?

Turnbull: No, well, what is the concept?

TJA: I assume at this stage the concept is to build fibre to the home...

Turnbull: I don't agree with that.

TJA: What do you agree with?

Turnbull: What I'm saying is that all Australians should have access to fast broadband at an affordable price.

TJA: Fast?

Turnbull: Yes, absolutely. There are two questions then, at least. One is how do you define fast? The other is what is the best technology, or mix of technologies, to achieve that? Now I would think, in terms of the government providing subsidies and so forth, you clearly wouldn't say that every Australian should have at least a gigabit per second to the home. That would be absurd. And I think 100 megs is way above what the vast majority of people would ever be reasonably able to use...

TJA: Yet no-one knows what may happen in the future...

Turnbull: No, but this is the point, Liz. The bottom line, I would say, is that we should say that every Australian should be able to access broadband at not less than 12 megs.

TJA: Is that Coalition policy?

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Turnbull: Well, it's the Government's policy too by the way...

TJA: At least 12 megs?

Turnbull: It's the Government's policy because what they're saying is that for the seven percent that can't get fibre to the home, 12 megs is good enough. Right? So 12 megabits per second will deliver any service that is currently available. There is nothing, you know, other than some... you get some crazy examples. We have these debates on Twitter. Someone will say, 'You know, well, what if I've got a family of five and we're all playing interactive karaoke separately in five separate rooms?' Well, OK, 12 megs might not be enough for you, but you're not typical, or not even remotely typical.

TJA: Isn't it difficult when technologies such as broadband satellite or terrestrial wireless determine the speed limit for the policy?

Turnbull: No, I don't think so. You've got to work out what you're trying to achieve.

TJA: Well, what is that?

Turnbull: Silence.

TJA: Please go ahead.

Turnbull: My proposition is this: that nobody seriously suggests that nowhere in Australia is there adequate broadband. The argument has always been that while there are some areas that have access to good broadband there are too many areas both in the cities and in regional areas that do not. Now what is adequate broadband? Obviously, there are millions of Australians who can get access to ADSL2 and ASDL2+ and even faster speeds over the HFC networks. So when you look at the sort of applications that are available, and likely to be available, and look at what the Government has done, they conclude that 12 megs is what people in regional Australia should be comfortable with.

TJA: Based on the limits of the existing technology though...

Turnbull: There is theoretically no limit to the speed you can make available between A and B. You can still have a gigantic pipe. In terms of the expense of this network, the big bucks are in the last mile, the fibre to the home or the fibre to the premises. What I'm saying is that I don't think that has been justified – I'm sure it hasn't been – and a better approach I think would be to ensure that all Australians have access to speeds that were comparable to, say, the best speeds available in the cities and then...

TJA: OK, so...

Turnbull: ...that's not saying that's the last word on the subject, but then you'll see what the market demands. And the big question – Liz, could you just stop talking over the top of me all the time...

TJA: I'm sorry, but I'm here to ask you questions.

Turnbull: You never let me finish a sentence. Go on, you talk, just talk. I have nothing further to say to you. On this topic, I have answered the question, you ask the next question.

TJA: Do you agree with the eventual privatisation of a publicly-funded NBN?

Turnbull: Well, I think the Government has asserted that the NBN will be commercially viable. I don't know anyone in the industry who believes that's feasible or credible. Again, this is one of the things we need to know. If you were to say everyone could have 100 megs per second, and it was not going to cost us anything – it was free and we could snap our

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fingers – then I suppose we would do that and have perfect public transport, and wonderful hospitals, and great schools and all those other things. But we live in a world of scarce resources, so we've got to have a clear understanding of what the NBN is going to cost, what it's going to cost in net terms after taking account of the revenues, and then weigh that up. Because you see, you get a law of declining returns, Liz. I mean if you've got speed on that axis, right…

TJA: On the horizontal axis...

Turnbull: ... and you've got utility, productivity, on the vertical axis. Well you go from dial-up to one meg and you'll get a pretty solid increase in utility. Then you go from one meg to 12 megs, well that's still going up perhaps, but then 12 to 50, I don't know how much more useful that's going to be, and 50 to 100, probably not more useful at all. Now, of course, the difficulty is that as you go up in terms of speed, when you move out of using your existing last mile to fibre, the cost becomes considerably greater. So one of the things you've got to weigh up is the incremental cost of these greater speeds – given the need to have a new communications medium versus the utility. That's the point of the cost-benefit analysis. That's the thing, for example, that Robert Kenny looked at in that paper he wrote with his brother, Charles. Every major infrastructure should be the subject of a rigorous cost benefit analysis.

TJA: You just said, 'given the need to have a new communications medium'...

Turnbull: ... I'm not saying there isn't a need...

TJA: Is your party's position that there is a need to build some sort of new communications network for this century?

Turnbull: Well, I think the communications network is constantly being renewed and rebuilt and transformed.

TJA: But surely less so in regional and rural areas, at least by the private sector?

Turnbull: (Silence)

TJA: Would you agree with that?

Turnbull: No, I wouldn't. You are putting words in my mouth. Because of distances, you know, products like ADSL2 are not going to be available in areas where people are living very long distances from exchanges, as they're very likely to be doing in the country. So you need a variety of technologies. The general view has been that the best solution in regional and remote areas is a combination of fixed wireless and satellite. That's actually what the NBN is proposing, and that's what we proposed to do with OPEL. So there's common ground about the technological solutions in the bush as such.

TJA: Do you still see OPEL as worth building on or are you ready to let the NBN go ahead?

Turnbull: Well, OPEL is a thing of the past. The Government has abandoned that. You can't snap your fingers and bring that back to life. I think that the solution in the bush, in regional and remote Australia, is a combination of fixed wireless and satellite. It will require a government subsidy, and we're certainly committed to providing that. What is the most cost-effective way of delivering that? Well, that's something we would have to look at more closely as the election, you know, as time goes on.

TJA: What do you think of the current review of the Universal Service Obligation (USO). Do you have a position on that?

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Turnbull: Well, basically, nobody is suggesting there should not be universal access to affordable broadband as well as voice, so the question then is: how do you define broadband and what is affordable? One of the concerns I have about the NBN is that because of what I believe is a massive overcapitalisation, and coupled with making it a government monopoly, that is inevitably going to put upward pressure on prices. It's no different from any other business: if you spend too much on your capital, you're going to have to try and recover that. Now if you're a monopolist it's easy to do that if you don't have competitors.

TJA: Can I move on to the questions you raised on your blog about the US Securities and Exchange Commission (SEC) findings that Alcatel subsidiaries were guilty of bribery in several developing nations? Are you suggesting NBNCo's CEO, Mike Quigley, and CFO, Jean-Pascal Beaufret, may have been involved because they are former Alcatel employees?

Turnbull: Well, the only issue I've raised is really that both Quigley and Beaufret need to explain what their knowledge was, what their role was, and how it came to happen. I mean, you've got to remember that Alcatel was being run by an executive committee of which Quigley was a very important member, and its chief financial officer, whose job is to know where all the money is going – both coming in and going out – was Mr Beaufret. So these were two very senior guys in a company that clearly had a systematic practice of paying bribes to people in developing countries in order to get contracts, and I think we are entitled to a full explanation.

TJA: Well, Quigley is quoted as saying...

Turnbull: Just keep talking, Liz, don't let me finish an answer.

TJA: Go on, please.

Turnbull: Alright. Quigley has said he didn't know anything about it, but it rather does beg the question of what were the systems, what was the accountability of people, what is the competence of people who could be running such a big company and then have what was clearly a systemic practice of corruption – I mean there's no question about that, it was operating in a whole range of countries – and so if they weren't aware that it was going on, why not?

TJA: A former Alcatel employee told me there was no doubt that Alcatel's culture was far from perfect and it wasn't till the merger with Lucent that this culture changed in line with the US legislation. It's quite complex isn't it, but when you were a partner of Goldman Sachs & Co., could you be held responsible for company actions in, say, Greece?

Turnbull: I wasn't involved in that. I had nothing to do with that.

TJA: Isn't that what Quigley is saying too?

Turnbull: No, no. It's very different. If I had been a member of the management committee or executive committee of Goldman Sachs and there were dreadful things going on within the company, people would be entitled to say: Why didn't you know about it? or, Didn't you fail in your duties by not being on top of this issue?

TJA: But apparently the culture of Alcatel didn't necessarily require answers to those questions...

Turnbull: That's not the point. The point is that you keep on talking over the top of me, you don't listen to what I'm saying, Liz. We'll have to wrap this up. I love you dearly, and you're a very old friend and everything...

TJA: Am I allowed to ask a few more questions?

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Turnbull: No, you don't ask questions. Just let me finish. The point I was about to make, which I think is a very significant one, is that in some respects the person who really needs to make a clearer explanation of his role in all of this is Beaufret, because Quigley was a member of the executive committee, there's no question about that, and the executive committee, as the SEC has said, ran the company. That's how it operated. Quigley's argument seems to be: 'Well, I wasn't directly involved. I didn't have any oversight of these particular areas.' But Beaufret was the chief financial officer. Now if there were very substantial payments being made to consultants in these countries, shouldn't alarm bells have been ringing for him? We haven't heard anything from him.

TJA: I understand the SEC didn't talk to him.

Turnbull: That's what we've been told, and without hearing from the SEC, it's hard to know why that was the case. You've got to bear in mind, Liz, that these gentlemen have been at the very top of a company that was engaged in a systemic practice of corruption around the world. That company has now admitted its guilt and paid a huge fine of, I think, $137 million. They are now running, between them, a company which will end up spending about A$50 billion of taxpayers' money. What I would like to hear from Mr Beaufret is, for example, how it was at Alcatel that he, as chief financial officer, was not aware that millions of dollars were being paid out in bribes in these developing countries. And I would like to hear from Mr Quigley how it was that the executive committee of Alcatel, and he as a member of it, never became aware of these things. I'm not suggesting that either of them was party to making bribes, but it does raise question marks about, I think the SEC used the phrase, 'lax management practices'.

Dart : We'll have to wrap this up.

Dart (to TJA): He does have to go.

TJA: He was 30 minutes late and I did ask for an hour.

Turnbull: No, keep going, Liz,

TJA: Can we move on to Wikileaks? As a former journalist and the author of Spycatcher, does this new development excite you?

Turnbull: I have written quite a long piece about it in The Age. I don't know that it excites me.

TJA: Would it worry you if you were quoted in a cable, though I guess it could always be inaccurate, which would be worrying!

Turnbull: That's exactly right. I'm sure some people have been genuinely embarrassed by it, but so what? As I think I said in *The Age*, you can divide the material up into at least three categories. The area which is of great concern, and I do have very real concerns about Assange's ethics here, is material which either reveals, or is likely to reveal, the identity of people who are informants to the State Department, particularly in areas of terrorism and counter-terrorism. I won't repeat what I said in *The Age*, but can I just say that I think in one respect the single biggest issue here is how on earth could a very junior person download a quarter of a million documents! In any big corporation or government department nowadays it should be the case that you cannot put a thumb drive into a computer without an alert being sounded. If you're working for a bank, and you put a thumb drive into the system, you should get a call from Security within minutes saying: 'What are you doing?' So either this guy, Private Manning, was a genius hacker or the system is just laughingly lax. I know plenty of people who work for banks and government departments who are just aghast that this could happen. Let's face it, Liz, it wasn't just one document that was downloaded. It was a gigantic amount of material.

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TJA: Given your experience with mainstream media, and as a banker you advised all three commercial TV channels, have you any thoughts on the Government's upcoming convergence review of media and communications regulation?

Turnbull: Well, there are some very big issues around this. The free-to-air networks, for example, would be saying,' Twenty years ago we were paying licence fees for the only way of getting something directly into someone's home', in effect, a monopoly. Now people can access video material from hundreds of different providers courtesy of the Internet and other technologies. So there has been a dramatic change.

TJA: What about Telstra's involvement in this area? You must have known Telstra's business quite well when you were at Goldman Sachs advising the Government on the T2 share offer.

Turnbull, Well, I'm not unfamiliar with it. Telstra's in the content business now.

TJA: Do you agree with the structural separation of Telstra?

Turnbull: Yes. I talked to Telstra about this a very long time ago. The problem is that once the Government had decided to sell Telstra as an integrated telco it was very hard for the Government to direct any change. I think that Telstra would actually have enhanced its shareholders' value if it had separated its network from the retail businesses, but that's not a unique view. There are plenty of other advisers and, indeed, executives at Telstra, who have held that view over the years. Obviously, you would have to get a satisfactory regulatory regime, and certainty about pricing and so forth, but you've got to ask yourself, Liz, would Telstra be stronger and more financially strong if its senior executives hadn't spent the last ten years fighting tooth and claw with the Government and the regulator and, instead, concentrated on expanding the business and focusing on new products? There's been a lot of missed products, I think, because they have been, in effect, under siege over this issue of vertical integration.

TJA: Wasn't some of this uncertainty related to building some type of next generation fibre network as well as Telstra extending its dominant position by remaining vertically integrated?

Turnbull: Well, if the NBN goes ahead, Telstra will be structurally separated because the customer access network will be NBN. It won't be Telstra's copper. This is a critically important point. If vertical integration is the problem and structural separation is the answer – which I believe it is – you don't need an NBN to achieve that.

TJA: How would you have gone about Telstra's structural separation?

Turnbull: I would ensure there was a separate company, a CANCo or Customer Access Network Company, and it becomes a regulated utility and every year they would rock up to the ACCC or an IPART-type entity and say, 'OK, we've spent $2 billion and for that reason, in order to get a reasonable return on our capital, we need these prices' just like Sydney Water or the electricity companies do.

TJA: How do you view the enormous task facing the NBN as it begins to build as well as prepares to operate a wholesale access network?

Turnbull: Look, there will be enormous engineering and technical and operational challenges for the NBN. I'm not suggesting for a minute, that the enterprise, from a technical or engineering point of view, is not feasible. I'm sure it can be built.

TJA: But it needs a cost-benefit analysis!

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Turnbull: There are two big questions. Number 1 is the cost effectiveness of it: are we spending vastly more money than we need to achieve the objective of universal affordable broadband? Number 2, there's also the industry structure issue which, in some respects, is just as important in that we are now creating another government-owned monopoly. If we believe that competition is important, why is NBN contracting with Telstra to prevent Telstra from offering broadband and voice services over its HFC network that passes three million homes or thereabouts and would provide real facilities-based competition. Now that's going to be made unlawful by this scheme.

TJA: You've said the NBN is 'a bit of a dream' and 'appeals to dreamers'. Do you still hold to these statements?

Turnbull: Well, I think whenever politicians talk about nation-building infrastructure, you want to start reaching for your wallet. I'm not suggesting that there isn't a role for infrastructure that helps build a nation – all infrastructure does that – but all too often they use that term to justify projects that haven't been well thought through. Again, Liz, I'm not against it. I'm madly in favour of broadband, indeed passionately in favour of it. My concern is simply cost-effectiveness. If we could deliver, for example, ADSL2+ speeds or better across Australia for a fraction of the NBN cost, why wouldn't we do that and then see where technology went? I mean Conroy talks about this on the basis of what demand may be in 30 years' time. We have no idea. Cast your mind back – 30 years was 1981 for goodness sake!

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The NBN Futures Forum

Social and Economic Benefits of Broadband for Digital Inclusion and Telehealth

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Abstract: On 18 August 2020, TelSoc hosted the fourth NBN Futures Forum, held online, on the theme of social and economic benefits of broadband. Three speakers discussed various aspects of the topic, including the need for universal digital inclusion, the benefits of healthcare delivery via telehealth, and the actions required of government to support telehealth availability. Discussion following the speeches emphasised the need for universal access to broadband and telehealth services to improve access to health providers and, through education, reduce social inequities and overcome some social determinants of poor health outcomes.

Keywords: NBN, public policy, digital inclusion, telehealth

Introduction

The NBN Futures Project (Holmes & Campbell, 2019) has been organizing a series of public forums under the title NBN Futures to encourage debate, and potentially to build consensus, about the future of Australia's National Broadband Network (NBN) now that the initial rollout is nearing completion. The forums are hosted by TelSoc (the Telecommunications Association Inc, publisher of this *Journal*). The first forum was held in July 2019 (Campbell & Milner,

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2019), the second in October 2019 (Campbell, 2019) and the third in February 2020 (Campbell, 2020).

The fourth forum, held online on 18 August 2020, was on the general theme of "Social and Economic Benefits of Broadband" and included speakers on digital inclusion and telehealth. Three main speakers addressed various aspects of this theme in short presentations. A moderated question-and-answer session online followed.

The NBN Futures Forum

Dr Jim Holmes, who chaired the event, invited John Burke and three subject-matter experts to address the theme of the "social and economic benefits of broadband".

John Burke: Context for the Forum

Mr John Burke, the convenor of the NBN Futures Group, sketched the interests of the Group to provide some context for the Forum. From its beginning, the Group had been concerned with the social and economic benefits of broadband access. There is a discussion paper available on the TelSoc website particularly addressing two relevant issues: realising the value of online activities *at scale*; and promoting digital inclusion.

Mr Burke welcomed the recent formation by the Minister of Communications of an Australian Broadband Advisory Council. It had a brief to advise on broadband applications for agriculture, health, tourism and other areas, but appeared to have no explicit focus on digital inclusion.

The NBN Futures Group aims to promote wider knowledge about online applications (such as telehealth) and digital inclusion: hence this Forum.

By the end of this year, it is hoped, the NBN Futures Group will outline proposals for a long-term, bipartisan, broadband strategy for Australia. As a step in this direction, the Group, via TelSoc, has made a submission, which is available on the TelSoc website, to the Joint Parliamentary Standing Committee on the National Broadband Network.

Ishtar Vij: Digital inclusion

Ms Ishtar Vij is convenor of the Australian Digital Inclusion Alliance (ADIA), founded in 2017 and now a grouping of more than 500 organizations. Its purpose is to accelerate digital inclusion in Australia. The COVID crisis has in many cases expedited digital transformation but it has also highlighted deficiencies in digital inclusion. Many Australian households do not have the technology or the ability to fully participate in online activities. This makes it difficult

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to use digital services, stay socially connected in a time of social distancing, and pivot their daily tasks to an online world.

It is a core tenet of the ADIA, according to Ms Vij, that all Australians should be digitally capable and able to participate in the digital economy. In addition to an Internet connection and a suitable device, people need the abilities to navigate and use digital services – and these abilities will require life-long learning to be kept up to date with new technologies and applications.

The Australian Digital Inclusion Index (Wilson, Thomas & Barraket, 2019) has been tracking digital inclusion. The 2019 index showed that the lowest levels of digital inclusion were found in households with low income or that were mobile only, and for those over 65. Further, Indigenous groups and those in rural and regional areas showed lower levels of digital inclusion.

The ADIA has identified about 50 programs, spanning government, business and community groups, that are addressing issues of digital inclusion. They are not well coordinated and are not necessarily targeting the most disadvantaged groups, with each program having its own goals and objectives. At the government level, there is no whole-of-government coordination. This leads to confusion for potential beneficiaries of these programs.

National Digital Inclusion Roadmap		
Affordability *Addressing access and affordability of Internet services* ~ Incorporating NBN rollout and wireless plans to demonstrate progress towards 100% connection across Australia ~ Assessing which COVID-19 affordability measures can be retained going forward ~ Support low income and vulnerable populations to access devices ~ Funding free public Wi-Fi access points	**Ability** *Ensuring everyone has the capabilities and confidence to benefit from and complete activities on the Internet* ~ Creating a Digital Capabilities Framework to provide a common understanding of what it means to be a digitally capable individual ~ Collating a central index of the programs available to support digital skills development in a searchable database ~ Conducting a gap and overlap analysis of the current digital skills development programs	**Accessibility** *Allowing everyone to use the internet including those living with disability, from culturally or linguistically diverse backgrounds, or with other needs* ~ Working towards all government websites being compliant with accessibility standards ~ Ensuring government adherence to accessibility requirements suitable for public procurement of ICT products and services ~ Incentivising the adult learning sector to incorporate inclusion and accessibility in ICT and design courses by 2022.

Figure 1. Proposed National Digital Inclusion Roadmap (Source: ADIA)

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The solution, according to the ADIA, is for government to develop a roadmap for digital inclusion and identify immediate action items. Early actions should include creating a digital capabilities framework, tackling affordability measures for broadband, and implementing the latest accessibility standards on all government websites.

The roadmap to digital inclusion should have three main areas.

- *Affordability*. Cost is a barrier to uptake of digital services and access is out of reach for some households. An NBN service priced at $20 per month for low-income households, as promoted by ACCAN (Corbin, 2019), would be beneficial. In addition, the cost of devices is a barrier to availability. It was noted that free public Wi-Fi is critical for many of those being excluded.
- *Ability* – capability and confidence – to use digital services. The government could undertake a gap and overlap analysis of current initiatives to identify who and what are not being covered. It could collate and maintain an index of initiatives, so that consumers could more easily find support. A national Digital Capabilities Framework, to promote a common understanding of digital capability, is required. The Commonwealth Department of Employment promotes a core skills framework that includes information technology skills, but it is only at a basic level and only for a limited purpose.
- *Accessibility*. Digital services should be accessible by everyone, including those with a disability or from linguistically diverse backgrounds. The government should lead by ensuring that all government websites meet the latest accessibility standards. Government acquisition should include accessibility as a criterion. Accessibility should be included in all ICT and design courses.

In summing up, Ms Vij suggested that the world would be different after the COVID crisis. The current, uncoordinated initiatives to promote digital inclusion urgently need coordination and strengthening.

Anthony Smith: Telehealth in Australia's health system

Professor Anthony Smith is the Director of the Centre for Online Health (COH) at the University of Queensland. The Centre was established more than two decades ago to pioneer and evaluate the use of telehealth and other online applications in the health system. This work is achieved through four highly successful pillars of work involving telehealth research, service delivery, teaching and consultancy. Whilst telehealth has been in existence for some time, the overall uptake of telehealth in mainstream practice has been slow and fragmented. The COH have a very practical focus in their research portfolio, working in close partnership with health services and helping to resolve problems associated with implementation, service

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transformation and sustainability. The COVID crisis had resulted in a massive surge in telehealth activity, mainly due to necessity (i.e. social distancing requirements and reducing risk of transmission for clinicians and vulnerable groups); and this itself introduces a range of important challenges, including the need for policy changes, new funding models, public awareness campaigns and health service provider training (Smith *et al.*, 2020).

Professor Smith described some telehealth success stories. In Queensland, a centralised telehealth coordination service was established in November 2000, for the coordination of telehealth referrals for a broad range of paediatric sub-specialities (Smith, 2007). The original Queensland Telepaediatric Service (QTS) resulted in larger numbers of patients being seen by videoconference instead of travelling to Brisbane for a specialist appointment. In 15 years, over 23,000 consultations were conducted for 37 different paediatric specialties. In the case of children with burn injuries, acute treatment was provided by the specialist burns unit in Brisbane, and follow-up appointments for post-acute burns care typically required return trips back and forth to Brisbane (Smith *et al.*, 2007a). The QTS scheduled follow-up appointments by videoconference with the support of local clinicians, such as nurses and occupational therapists. The success of this service was dependent on a dynamic burns team willing to change the way they provided outpatient burns care, a network of nursing and allied health staff in regional areas to provide support to patients during the telehealth appointment, and regular training sessions (online) to support staff in these areas with the delivery of specialist paediatric burns care. Whilst there was some initial reluctance within the department to do telehealth, the specialist burns centre have led the way in making this modality a routine part of their clinical service.

A second successful example of telehealth relates to the establishment of a community-based ear screening service for Indigenous children at risk of ear disease. A van was converted into a mobile clinic where a local Aboriginal health worker could travel to nearby schools and screen children for hearing-related health conditions. Clinical information was uploaded from the van to a secure database and made available to specialists based in Brisbane. Ear, Nose and Throat specialists were able to assist with diagnosis and treatment plans. Results demonstrated improvements in the overall proportion of children being screened from 35% to over 80% of children in the supported communities (Smith *et al.*, 2015; Nguyen *et al.*, 2015). This is an example where telehealth has enabled a more responsive service and demonstrated the importance of community leadership.

In 2012, the COH had a unique opportunity to help design and establish a new centralised telehealth centre at the Princess Alexandra Hospital (PAH) in Brisbane. Based on a similar model to the QTS, routine telehealth clinics were planned for a range of clinical specialities at the PAH for mainly adult patients (Martin-Khan *et al.*, 2015). Within the first eight years, the

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total number of telehealth consultations reported per year in this health service increased from around 400 in 2012 to over 15,000 in 2020. In addition, the service has expanded into a hybrid model where activity is either conducted in the telehealth centre (centralised) or in other locations (satellite sites) – such as outpatient clinics or consultant treatment rooms. The effort at the PAH reflects significant changes in referral procedures, staff training, infrastructure support and the development of new clinical service models.

Professor Smith wanted to dispel some common "myths" about telehealth:

- *It is not just about remote communities*: telehealth consultations are now being used with patients only 2 km away from the specialist hospital in Brisbane. Barriers to face-to-face consultations, such as physical or mental health disability, affordability or cultural factors, can be overcome with telehealth.
- *It is appropriate for older people*. While Professor Smith has found that many older people already embrace telehealth (in the form of videoconferencing with family and friends), a successful telehealth service needs to be well designed and cater for specific requirements of potential users – such as audio and visual capacity. Provided that the systems being used are appropriate and that the necessary support and training is in place, telehealth should not be a problem.
- *It is never going to replace all face-to-face consultations*. Telehealth supplements interactions with patients and an appropriate balance between in-person and virtual consultations needs to be found. If a specific physical assessment is required, then a face-to-face appointment may be required. If no physical assessment or specialised procedure is required, then telehealth ought to be considered.
- *It does not necessarily provide cost savings*. It is easy to assume that, because telehealth can reduce the need for travel, this also implies massive savings overall. Sometimes this is the case, but one must be mindful of the true cost of providing telehealth (infrastructure, staffing etc.) to articulate these savings and the actual beneficiaries. Patients are more likely to realise savings, rather than the health service. Rather than focus on telehealth as a cost-saving exercise, it is more appropriate to invest in telehealth as a method of enabling more timely access to health services and improving healthcare overall.
- *It is not necessarily quick and easy to do*. It does take time and effort to properly plan, implement and operate a telehealth service. Telehealth is a disruptive process, which can result in major changes in the way healthcare is delivered.

What makes telehealth successful? It is certainly more than just implementing a technology. Professor Smith suggested the following organizational components are important:

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- The clinical requirements must be clearly identified. This determines the most appropriate modality, technology, setting, and patient groups where telehealth may be safely and effectively used.
- There must be organizational support, not just from management but also "bottom up": that is, clinicians must be trained and supported to take up the new way of working. Clinicians who are unwilling to practice telehealth can certainly have a negative influence on acceptance and uptake of telehealth.
- There is an important role for "clinical champions" who are enthusiastic supporters of telehealth and can encourage colleagues to participate.
- There must be sustained funding, not only to support ongoing training and service development, but also to ensure that people who have key roles in the planning and delivery of the telehealth service are remunerated appropriately.
- There is an ongoing role for change management to ensure that the new models of service are sustained and treated as business as usual.

Telehealth adoption is certainly not restricted just to hospitals, Professor Smith emphasised. We are seeing excellent examples of telehealth being used in general practice, in nursing homes, in community health clinics, in the home and in schools. For example, a Health-e-Regions project in the Western Downs is helping to deliver telerehabilitation services into schools for children who need speech and language or occupational therapy (Langbecker *et al.*, 2019).

The widespread possibilities for telehealth have been shown in the COVID crisis (Smith *et al.*, 2020). After the Australian Government relaxed the funding rules associated with the Medicare telehealth items, the number of consultations reported nationally has increased substantially. Before the COVID crisis, around 250,000 telehealth consultations were being funded by Medicare each year. Between March 2020 and June 2020 (four months), the total number of telehealth consultations reported was over 17 million. Over 90% of these consultations have been by telephone. Temporary relaxations to MBS funding for telehealth has broadened the types of services available by telehealth, and enabled easier access, irrespective of physical location.

The Medicare funding changes have been approved until September 2020, but Professor Smith argued that they should be maintained for the longer term with some modification. Telehealth can help to address continuing social distance requirements, can provide a safe space for patients, and can be safer for healthcare workers. While the tragedy of COVID is still being felt around the world, the pandemic has created the impetus for clinicians to rethink the way they provide services, and for the general public to increase their understandings and awareness of telehealth.

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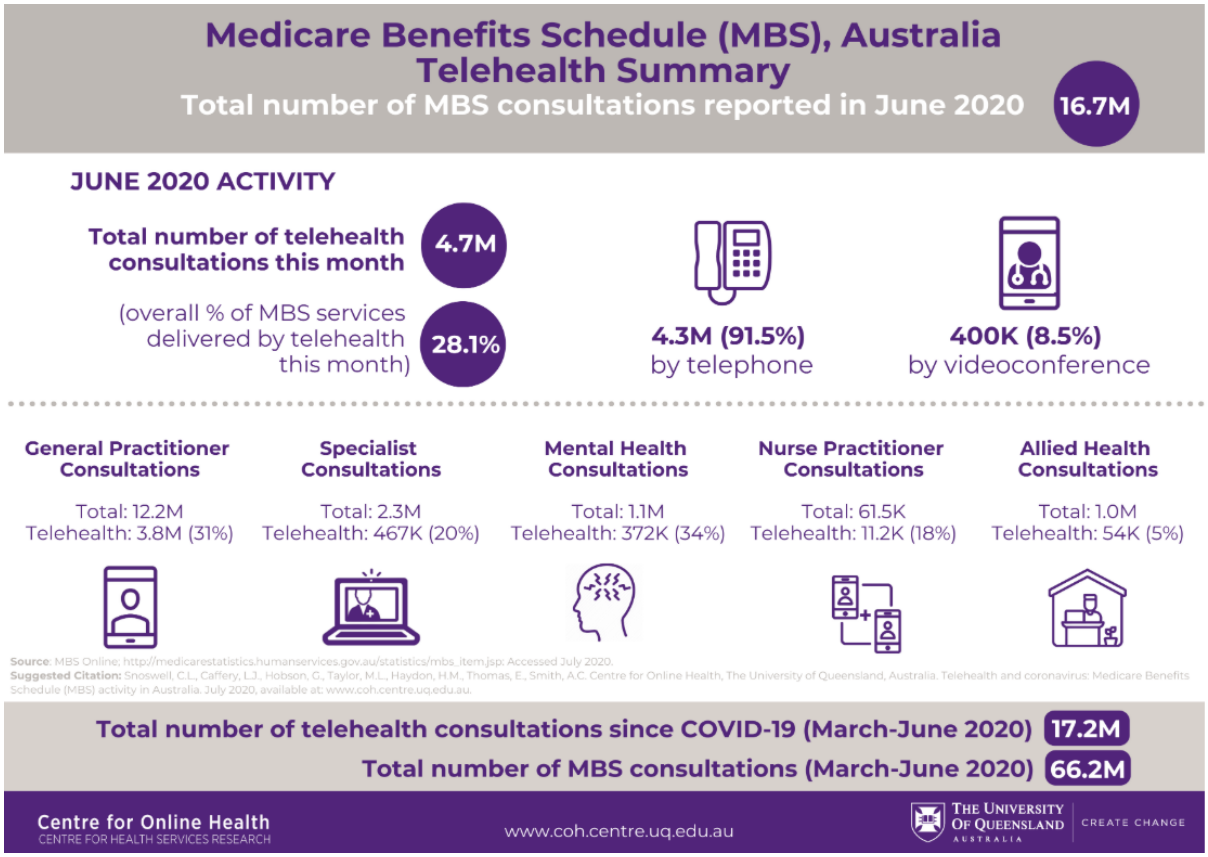

Figure 2. Telehealth consultations reported in June 2020 during the coronavirus pandemic
(Source: Centre for Online Health)

Professor Smith wished to emphasise three points in summary: telehealth is complex but achievable in the right circumstances; it generally improves efficiency in the health system (coordination and access to services); and it also encourages the development of new models of care that are much more patient-centric and equitable.

Peter Brooks: Telehealth and social inclusion

Professor Peter Brooks is with the Melbourne School of Population and Global Health at the University of Melbourne. He addressed the systemic issues around healthcare and telehealth and the actions needed to promote change.

He suggested that the current system is not particularly patient friendly and is often too complex for patients to navigate. It can be inefficient and wasteful and produces significant inequities in outcomes. Telehealth can help to enhance patient engagement, presenting patients with options and often producing better outcomes. Telehealth technology can be an enhancer but the underlying need is to upskill the healthcare workforce and the community.

Professor Brooks noted that implementation is not only about technology but is primarily a change in culture. He cited the example of the US Veterans Affairs Department, a generally conservative organization with 10 million patients and over 1,200 healthcare facilities. Two

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years ago, it reported that 75% of its consultations were via telehealth. This was the result of a management drive over a three-year period to change the culture of the organization to achieve better healthcare outcomes.

Professor Brooks suggested that telehealth can address the social determinants of successful health outcomes. There was evidence for this from the examples provided by Professor Smith and other clinical trials. He feared that overcoming detrimental social determinants would only become more important in the near future with higher unemployment levels, poorer economic growth and education challenges.

Professor Brooks believed that there were three sets of actions that are required:

- Funding is important – it is necessary to lobby politicians about keeping the telehealth changes after September, while being mindful that public money should be carefully used. Professor Brooks suggested that all health professionals should have access to telehealth funding arrangements.
- A new workforce – digital health "navigators" – may be important to help people find and connect to telehealth facilities.
- There is a need for conversations with patients to strike the right balance between face-to-face and online consultations.

Questions and discussion

Questions and discussion online followed.

What could be expected in telehealth developments if the government did not lead?

> Professor Brooks believed that the government must provide leadership and have a continuing role in telehealth developments, to protect the most vulnerable members of society. The private sector can also play a part.
>
> Professor Smith noted that there were many private companies already providing a range of telehealth services. This could potentially pose a risk in terms of generating services that lack continuity of care with primary care providers. Recent changes to MBS telehealth funding rules now stipulate that patients must have seen their GP in person within the last 12 months to qualify for the bulk-billed payment.
>
> Professor Smith also noted that there was currently no gap fee permitted for telehealth services provided by GPs. In the current arrangements, GPs can only bulk-bill telephone and video consultations. If a gap fee was permitted, he believed that most people would be willing to make a reasonable payment, because of the convenience of the appointment (such as avoided time off work, travel and parking costs). However,

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it is also important that bulk-billing options still exist, for specific circumstances where patients cannot afford the gap payment.

Is it the case that low-income groups are harder or more expensive to engage to promote digital inclusion?

Ms Vij reported on the outcomes of focus groups on low-income communities. There were expressed concerns about access to suitable Internet plans. On affordability, even if a plan was affordable now, would it continue to be affordable in the future? Credit checks that are required for post-paid plans may not always be available, restricting users to prepaid, mobile-only plans. Identity verification is also required, but relevant documents may not always be available and some groups may lack confidence in sharing them. These barriers can lead to social and digital exclusion.

For a whole-of-government strategy, where should the leadership and coordination be located?

Ms Vij reported that the ADIA had no fixed view on this matter. She cited examples of coordinating bodies as a committee of government, or at Ministerial level, or at the level of Department Heads, or even as a unit in the Department of Prime Minister and Cabinet. All of these could be successful. To coordinate efforts at the State level, she suggested that a lesser version of the National Cabinet method could be set up.

Post-COVID, should telehealth by telephone be continued? How will the potential loss of income by GPs be addressed?

Professor Smith suggested that over 90% of consultations were being done by phone because it was easy and convenient. A telephone consultation is certainly appropriate for many routine services: it depends on clinical requirements. Anecdotally, some GPs have been reporting a loss of income because the current funding guidelines do not permit a gap payment to be charged for telehealth consultations.

He suggested that there is a need to explore ways of encouraging more video consultations. For example, an integrated system, which permitted easy access to documentation, video connections, billing processes, and scheduling procedures, might be attractive. For government policy, remuneration should be based on effort and outcome: video consultations might attract a higher remuneration value than telephone services, depending on patient needs.

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Physicians have said that colour is important in assessing patients. Can suitable colour be provided on video in variable lighting conditions?

Professor Smith described the case of burns surgeons who originally expressed the importance of interpreting the colour of a scar. An efficacy study revealed that colour interpretation was less important than specific observation of texture, range of motion and contractures (Smith *et al.*, 2004). To calibrate colour impressions between different viewing devices, a common technique is to place a colour chart next to the area to be assessed, so that a comparison can be made. This technique is often used in dermatology and wound care.

Is there data available on costs and benefits of telehealth in Australia?

Professor Smith noted that there is a growing number of economic evaluations being done in telehealth. Some of these studies have been in the form of a cost minimization analysis (Smith *et al.*, 2007b; Smith, Scuffham & Wootton, 2007; Xu *et al.*, 2008). Assuming the same clinical outcome, the costs and potential savings are compared for different service models – such as telehealth, visiting outreach service, or patient travel. Professor Smith's studies have shown that at certain workloads (volume of activity) telehealth is less expensive. Given that there are upfront costs for implementing a telehealth service, the studies have also shown that, if a workload is very low (small number of consultations), then it may be cheaper to provide an outreach service or continue to have the patients travel for in-person appointments.

Given the widespread availability and capability of modern smart phones, could all telehealth be delivered via smart phones?

Professor Smith agreed that smart phones were generally suitable, but, as well as access to a phone, there was also the need for connectivity and a sufficient data plan. In some Indigenous communities, there was a practice of sharing phones. This was not the ideal arrangement for providing mental-health consultations, for example. There were also examples of patients who experience difficulty accessing reliable Internet connections close to where they live. Some patients report using the free Wi-Fi in the local library or at the McDonalds, but these are often limited in the amount of time available, network quality and privacy. These examples highlighted some of the disparities which exist throughout Australia.

Professor Smith noted that telehealth need not be high tech. He described a telemedicine service (Swinfen Charitable Trust) which uses email to support doctors, nurses and health workers in developing countries — all around the world, including Nepal, Iraq and the Solomon Islands. A clinical question would be sent to a single email

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address. A panel of volunteer specialists provide expert clinical advice regarding diagnosis and treatment, and this information is returned by email back to the original referrer. This service is provided at no cost. He also described one orthopaedic case example from Bangladesh, which was raised at a conference attended by orthopaedic surgeons. Collectively, these experts discussed the case and helped formulate a response back to the referring doctor. These types of 'low cost' telehealth services could be just as valuable throughout Australia, he believed.

Can telehealth be used for allied healthcare, such as nursing or physiotherapy?

Professor Smith replied that telehealth was relevant for nursing and other allied services. The Medicare data showed that, after the COVID-induced changes, there have been 54,000 consultations for allied services, of which 11,000 were for nursing. There are many excellent examples of allied health services being delivered by telehealth. For physiotherapy, rehabilitation services can be delivered to patients through laptops or iPads. Australia's health service could benefit from an expansion of nursing and allied health services, and less reliance on purely medical models of care.

What regulation is required to avoid rorting of telehealth systems?

Professor Brooks indicated that having one's normal GP involved was important. It would be beneficial to have all patients registered with a GP, as in the UK NHS. He suggested that bundled payments to manage a patient may be appropriate. He regretted that, nevertheless, some overservicing would still occur.

Professor Smith noted that there were standard auditing processes to identify potential issues with clinicians' incomes. The COVID crisis had provided an opportunity to open up Medicare payments for telehealth. There had not been a budget blowout; there had been some increase in expenditure but perhaps this was an indication that fewer people were missing out on appropriate healthcare.

Given future online growth, what broadband capabilities should be provided?

Ms Vij reiterated the ADIA's position that all Australians should have options for affordability, ability and accessibility.

Professor Brooks concurred that all Australians should have broadband access.

Professor Smith saw developments for telehealth in three areas. On equity, there were still areas without reliable or affordable Internet. He believed Internet access for telehealth should be available everywhere and at no cost to the patient. For the healthcare workforce, there was a need to train up health professionals in the planning and delivery of telehealth. Telehealth should be a standard part of the training

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curriculum. For patients, they should be well informed and capable of accessing telehealth services as close to home as possible.

Conclusion

This was the fourth of a planned series of forums related to the topic of the future of the NBN. The theme of this Forum, social and economic benefits of broadband, has been a central concern of the NBN Futures Group since its formation. The Australian Digital Inclusion Index has been tracking digital inclusion and continues to show that there are significant groups, including low-income households and older Australians, who have high levels of digital exclusion. The COVID crisis has exposed the difficulties with poor online access, with many pupils struggling to access online classes and resources, and workers unable to access the resources needed to work from home or improve their employment prospects.

Digital exclusion is a known problem. There is an urgent need for government leadership to provide a roadmap for improving digital inclusion. In addition to ensuring affordable Internet access and accessible services, the government should enhance the opportunities for people to become digitally capable, so that they can participate fully in the digital economy.

Telehealth is a major application in the digital economy and for digital transformation. There have already been many success stories, as Anthony Smith described. Changes due to the COVID crisis have uncovered a pent-up demand from patients for online medical consultations, mostly conducted by telephone. This is a start but there is clearly the potential to use more advanced features of the online world, such as video, for more detailed consultations. New systems integrating medical records, video access and billing may encourage such usage.

One issue demonstrated by the changes to the Medicare Benefits Scheme is that clinicians must be appropriately compensated for their activities. The changes have not led so far to a major cost increase for healthcare, but several Forum participants were worried that they opened up opportunities for overuse or fraud. Continual monitoring and regulation will be required to ensure that telehealth is used appropriately and does not compromise continuity of care. Both Anthony Smith and Peter Brooks expressed the hope that the new vogue for online consultations is leading to improved healthcare outcomes. Both also believed that the changes should be continued beyond September.

Anthony Smith made the point that a telehealth service is not always cost effective: given the upfront costs, it may not be worthwhile for low levels of activity. Combinations of remote access, onsite visits and other new ways of working will be appropriate, depending on clinical requirements. As Peter Brooks noted, the introduction of telehealth processes is primarily a

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culture change for the healthcare system and, as such, it requires careful and continual change management. A willingness to change is as important as the underlying technological capability to support change.

The prominence of telehealth in the COVID crisis is exposing current weaknesses in Australia's access to broadband and inequities in participation in the digital society. The lessons learnt from the telehealth example will be important in reshaping the digital economy and delivering to everyone the social and economic benefits of broadband.

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Pricing in Abundance

The Economics of the Manatua Cable

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Abstract: Small island nations that have relied on satellites for international connectivity are now being connected by submarine cables that have infinitely more capacity. The hope is that these cables will lift the social and economic development of the economies connected. This hope is more likely to be realized with the adoption of wholesale traffic pricing based on the capacity abundance brought by the cable system rather than historical wholesale bandwidth pricing, which assumes capacity scarcity.

Reductions in the wholesale cost of international connectivity are more likely to be passed on to end users if there is retail competition. The proposed wholesale pricing model facilitates increased retail competition.

These ideas are explored in a case study of the Cook Islands, which is a member of the Manatua Cable Project.

Keywords: pricing, submarine, traffic, bandwidth, wholesale

Introduction

Cook Islands comprises 15 small islands, spread over 2.2 million square kilometres, between American Samoa and French Polynesia, south of Hawaii. The islands are home to a population of approximately 17,500 people with 75% of the population concentrated on the island of Rarotonga. There are at least four times as many Cook Islanders living in New Zealand and Australia.

Its per capita GDP is high compared to many other Pacific island countries. Tourism accounts for 60% of the GDP of the Cook Islands, well ahead of any other industry or exports. More than 160,000 tourists visited in 2017 with nearly three quarters coming from Australia or New Zealand. Aside from tourism, the Cook Islands' economy is supported by primary industries like fishing, with most exports going to Japan and Thailand.

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The 3,600 km Manatua One Polynesia Cable was completed in July 2020 and connects Apia in Samoa, Niue, Rarotonga and Aitutaki in the Cook Islands, and Tahiti and Bora Bora in French Polynesia. The cable will be capable of operating at up to 10 Terabits per second (10,000 Gigabits per second).

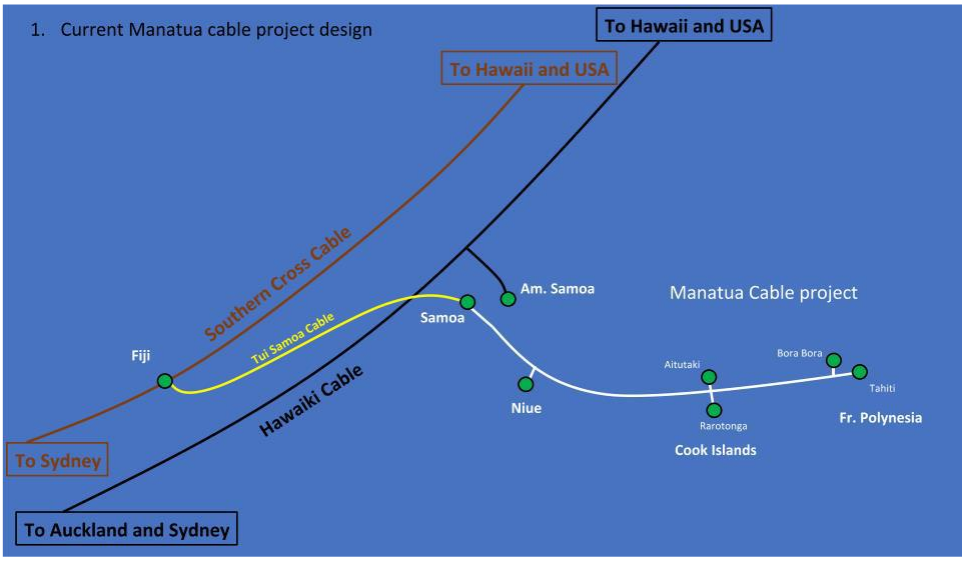

Figure 1. The Manatua Cable System (Government of the Cook Islands, 2019)

The Cook Islands had less than 2G (Gigabits per second) of satellite international connectivity and now has 200G lit out of the potential 10,000G. Adding submarine cable broadband capacity to existing satellite capacity is a move from scarcity to abundance. International capacity was the bottleneck in telecommunications — but not anymore. As demonstrated in an animation from NBN Co (NBN, 2020), congestion occurs when only one toll booth on the information superhighway is open. With the submarine cable, the Cook Islands has a bigger information highway than it can use. It can therefore open all its toll booths. If a wholesale customer wants 1G of bandwidth, ten times more can be provisioned. Speed does not have to be constrained and there will never be an international bottleneck.

This is a structural change that requires a change in the conduct of wholesale pricing to realize significant performance benefits for the Cook Islands – and others in the same situation of abundance.

The Cook Islands

The Cook Islands has a single retail telecommunications operator, Vodafone Cook Islands (VCI, also known as Telecom Cook Islands; formerly trading as Bluesky Cook Islands), with additional market entry envisaged under a new statutory regime. The sector is now overseen by a new independent authority, the Cook Islands Regulatory Authority (CRA). Its first commissioner was appointed in March 2020.

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Avaroa Cable Ltd. (ACL) operates the domestic submarine cable linking Aitutaki and Rarotonga, as well as the Manatua Cable links to Samoa in the West and Tahiti in the East. While ACL is to remain a crown corporate entity, it is government policy to substantially sell its remaining interest in VCI.

There are sound economic and social development arguments for a cheap link to Aitutaki. This link will be used for both domestic traffic (e.g. intra-islands communications including schools and government offices) and international traffic.

Providing international connectivity westwards is attractive because the Cook Islands has close legal, cultural and economic ties with New Zealand and similar ties to Australia. Also, for the best performance over a submarine cable (i.e. for 'low latency'), the best route for international connections out of the Cook Islands is via Samoa (Brewer, 2019).

The Cook Islands' participation in the Manatua Cable project is supported by a $15 million grant from New Zealand's Ministry of Foreign Affairs and Trade and a $15 million soft loan from the Asian Development Bank (to be serviced after a two year grace period ending April 2023). The more capacity or traffic that ACL can sell, the lower the unit cost.

While the cable was ready for service in July 2020, no commercial service had been launched by ACL for the single wholesale customer at the time of writing (August 2020).

The Cook Islands needs lower input costs for international connectivity to be passed on in lower prices to end users. This conduct is more likely with retail service competition than with the current retail service monopoly. Market liberalization is government policy but the form the market restructure might take is an open question, and one that is not discussed in this paper; except to say that a new form of wholesale pricing would encourage small new entrants.

Wholesale Pricing

The cost of satellite capacity consists of low fixed costs (dishes) and high recurring capacity costs. Submarine cables carry a high capital (fixed) cost and very low variable costs. For the submarine cable, the costs of depreciation and the return to capital are fixed because they are driven by the investment in the cable system. These costs usually represent two thirds or more of the revenues required to recover all costs. In the case of the Cook Islands, international soft loans and grants reduce the amount needed to pay investors and possibly the amount needed for depreciation.[i] Even though the useful life of a submarine cable is normally 25 years, it will need to be replaced eventually, and therefore some provision for depreciation is required. But the variable costs of a submarine cable are very low. It costs no more to provide a wholesale customer with, say, 1G than 10G.

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Transmission capacity has traditionally been sold on throughput measured in G (Gigabits per second), reflecting the historically or geographically limited capacity of long-haul transmission networks. Bandwidth pricing divides up the fixed bandwidth of an international transmission pipe in defined fractions. Each buyer is guaranteed a throughput speed but pays for the amount purchased, regardless of how much is used. Wholesale customers must acquire more capacity than they need to meet peak demand. Using the analogy from the animation cited above, the customer may need to pay for an extra toll booth to cater for peak demand.

Rather than charge for throughput (bandwidth), an attractive alternative is to charge what is put through the cable. That is, traffic pricing charges for what is actually sent though the pipe. It is simple: just a fixed price per month plus x cents per GB (Gigabytes where 1 GB is 1,000 Megabytes). It is like charging for water by the litre. Using the highway analogy, all the toll booths are open and the customer is charged for each car and truck that passes through. In the ACL case, if the wholesale customer needs 1G, ACL can provision 10G, which costs ACL no more and the wholesale customer pays only for the GB of traffic carried.

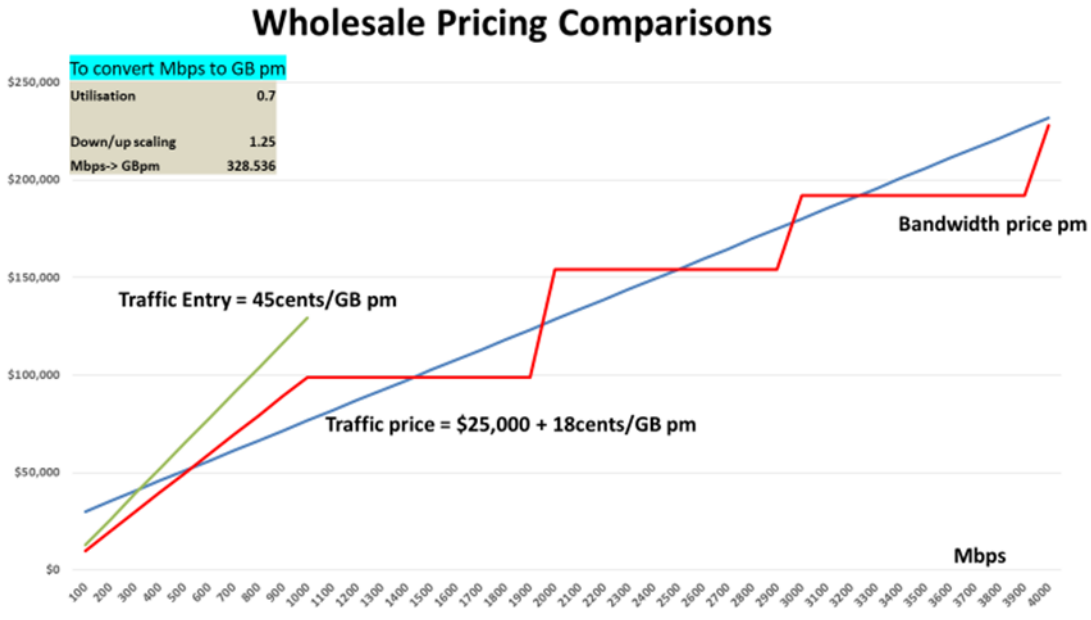

Figure 2. Illustrative comparison of bandwidth and traffic pricing

The two pricing approaches are illustrated in Figure 2. Bandwidth pricing for the new cable system in the Cook Islands is not yet known so the prices shown are hypothetical with a minimum capacity purchase of 100 Mbps. In order to compare capacity pricing with traffic pricing, some assumptions have to be made about what traffic a given amount of purchased capacity will support. Here it is assumed that each Mbps delivers 328.5 GB per month before assuming 70% utilization of purchased capacity and adding uploads at one quarter of downloads (i.e. both-way traffic measured). These assumptions are consistent with industry

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practice and have been calibrated to make the costs of each pricing regime roughly comparable.

The green line in Figure 2 shows how the traffic pricing approach also allows for a self-selecting entry level tariff that lowers entry barriers. There will be a break-even level of traffic per month, after which the normal traffic price is selected by the wholesale customer.

Importantly from an efficiency point of view, with traffic pricing there is no unused capacity for the wholesale customer. And, behind every byte of traffic is a paying retail user. Every byte is profitable. There is no need to make Retail Service Providers manage international bandwidth as there is an enormous excess of bandwidth on the new cable system.

The rate card for capacity pricing usually exhibits bandwidth multiples; such that 5 means that buying 10x more capacity costs only 5x more. From the perspective of cost-based price regulation, these volume discounts do not make sense. The unit cost is the same whether 1G or 10G is sold. Volume discounts can also lead to "one desk", where ACL might have no small customers because VCI uses its large volume discounts to resell capacity at a profit.

The main differences between the two pricing approaches are summarised in Table 1.

Table 1. Features of bandwidth and traffic pricing

Item	Feature	Bandwidth Pricing	Traffic Pricing
1	Speed	PIR constrained	No constraint
2	Retail pricing	Unlimited retail data	Unlimited retail speed
3	A paradigm shift	Tradition (scarcity)	Fibre (abundance)

1. Speed

Bandwidth pricing requires the wholesale customer to choose the guaranteed throughput (the CIR, committed information rate) and the maximum throughput (the PIR or permitted information rate). If bursting above the PIR occurs for more than 5% of the time, there are penalties.

High prices for bandwidth put pressure on the wholesale customer to purchase less capacity. Step changes in purchase requirements discourage smaller operators and cause all operators to use contention to get more out of limited capacity. They buy only what they think they can use. The ICT consultant, Matthew Mann, told me that, for ISPs:

> Their capacity management is very challenging, as they need to provision 80% of their traffic, and then when they have a growth spike they need to scramble to ensure they don't start dropping traffic due to exceeding the 95% percentile conditions on their commitment. Troublesome, but the industry is used to it.

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With bandwidth pricing, VCI buys, say, 1G from ACL. This speed is guaranteed. It is the committed information rate (CIR). But, with fibre, potential throughput is virtually unlimited – capacity is abundant. Why ration it?

When the international link has abundant capacity and deploys traffic pricing, wholesale customers and their end users will get faster speeds than they would under the bandwidth capacity pricing model, where wholesale customers squeeze as much as they can from purchased capacity.[ii]

With traffic pricing, bursting is encouraged. There is no CIR and no PIR. With traffic pricing, every GB is profitable because it is caused by and charged to a retail customer. And there is no step change in required purchase capacity so that there is a strong incentive to increase demand because it will not degrade the user experience. No traffic is dropped and services that might otherwise be throttled by the ISP will run unthrottled, potentially leading to revenue growth – subject to retail pricing.

2. Retail Pricing

In Australia, retail plans were formerly priced on monthly data caps. Now few are. "Unlimited" has become standard. ISPs do this because they understand consumers are prepared to pay for certainty.[iii] But unlimited data is dangerous because charging for data is the best way not to be relegated to a "dumb pipe service".[iv]

In the Cook Islands prepaid mobile plans:

- have no excess data charges. If the allowed GB is used up before expiry of the plan, the customer sends a text to his or her provider asking for another plan.
- there are no speed restrictions. You get what you can from 3G or 4G mobile – the device is the source of constraint, not network capacity.

The scattergram in Figure 3 plots prepaid plans in some Pacific markets. The five sets of Digicel plans are in markets that have had international submarine capacity for some years. The Solomon Islands (Our Telekom and Bemobile) and the Cook Islands (VCI; formerly Bluesky) obtained such capacity for the first time this year.

It is not surprising that markets dependent on expensive satellite capacity have relatively expensive retail plans. Digicel PNG is the expensive exception because it is a virtual monopoly with over 90% of the market.

In the Cook Islands, as the sole supplier at least for the time being, VCI's monopoly provides the opportunity to hold back passing through some of the lower costs due to the transition to

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submarine capacity. It could conduct itself like Digicel PNG. If that happened, its conduct would limit improved performance for the Cook Islands.

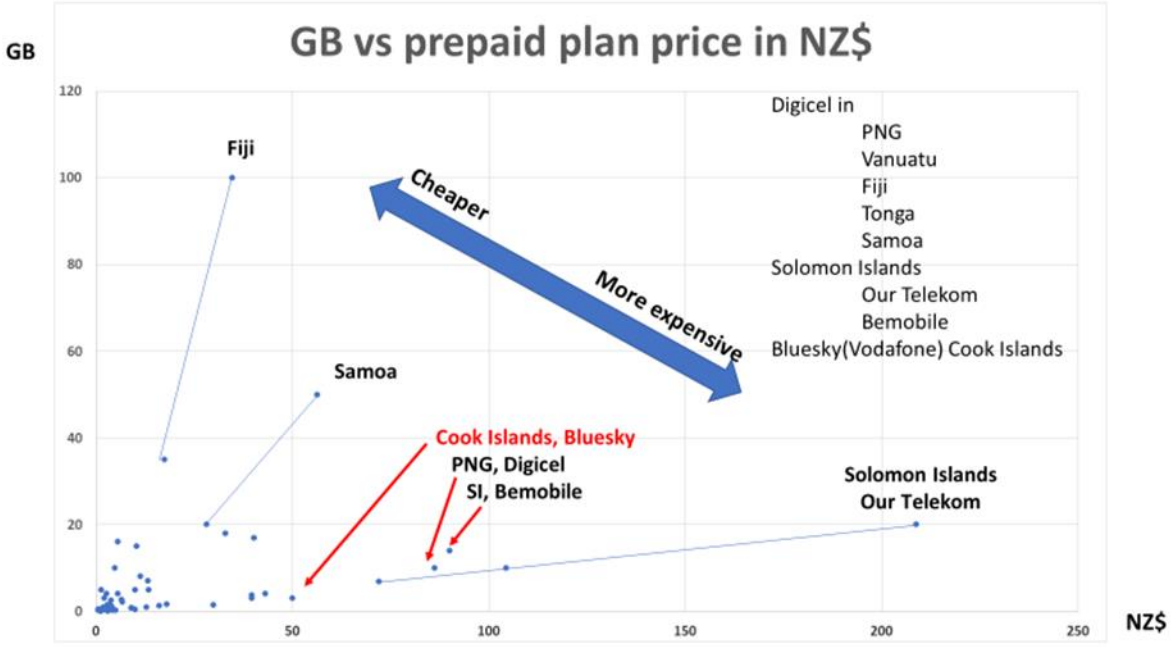

Figure 3. Prepaid pricing in selected Pacific countries (sourced from websites in May 2020)

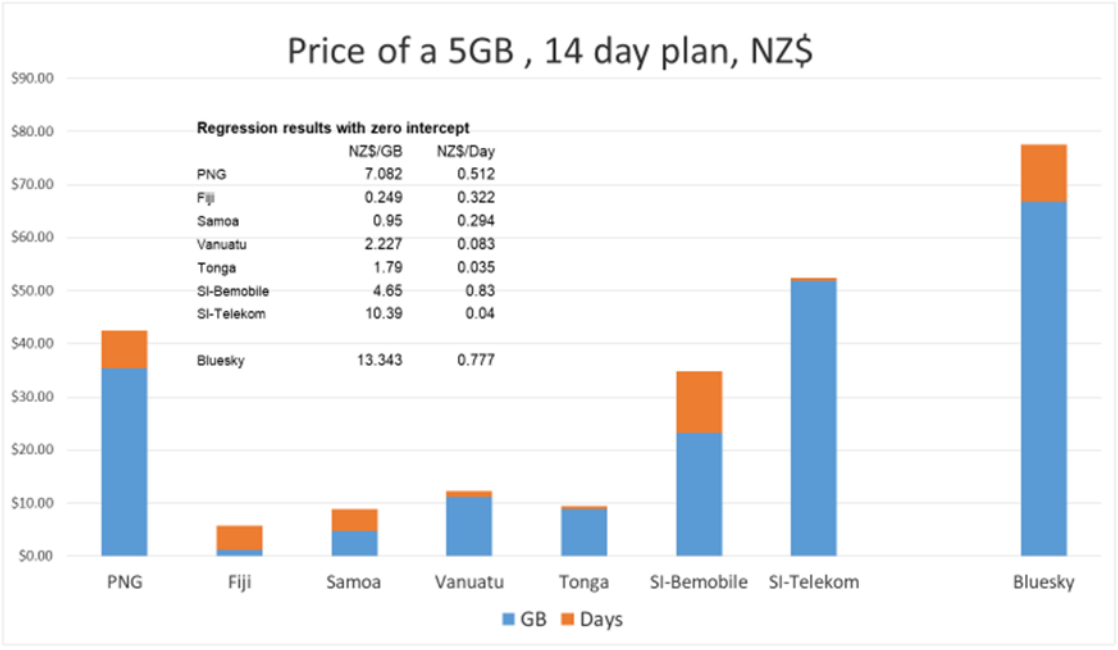

Figure 4. Decomposition of prepaid plan costs (author's analysis)

Prepaid plans are usually priced for both GB data allowances and term (hours or days validity). With 'best-fit' (regression) coefficients, we can make direct comparisons for a notional prepaid plan. Data is the main driver of price in most markets as shown in Figure 4, with the exceptions of Digicel in Fiji and Samoa.

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Figure 4 is based on the same prepaid plans shown in the scatter plot in Figure 3. The Cook Islands, Solomon Islands and Digicel PNG have the most expensive retail data; all are over $4 per GB. The simple average in four Digicel markets (excluding PNG) is $1.30 per GB, one tenth of the current price in the Cook Islands.

Technically, there is no reason for prepaid pricing to change with traffic pricing. Prepaid users probably feel they have good control of their budgets with this regime. VCI can continue with this form of pricing whether wholesale is priced on bandwidth or traffic, passing on savings though reduced plan prices or including more data in each plan.

VCI's current postpaid plans charge for both data and speed. Promised speeds range from 2 Mbps to 12 Mbps on the fixed network. Much faster speeds are possible over newer mobile technologies and there is no reason to limit speed due to international connectivity.

With bandwidth pricing of submarine cables, nothing much will change in the market. It is how satellite capacity is priced now. There will be a short-term boost from lower prices of international capacity (followed by pressure from future satellite pricing) and the speeds should be higher (constrained only by local access networks). That's it.

With traffic pricing and competition, artificial restrictions on speeds may disappear. This is what happened in New Zealand. For unbundled bitstream (broadband), Telecom New Zealand (TNZ) charged business customers more than residential customers. When the NZ Commerce Commission set a price for wholesale bitstream services supplied by TNZ, it ruled that there was no difference in cost between supplying a wholesale service intended for business versus residential users. Faced with a single wholesale rate, TNZ was the first to make its retail prices the same for business and residential users – to forestall other operators poaching its business customers.

3. A Paradigm Shift

On 5 August 1856, the Atlantic Telegraph Company completed the first trans-Atlantic submarine telegraph cable. It was a simple affair with seven copper conductor wires, wrapped with three coats of the new wonder material, *gutta-percha* (or, as we know it today, rubber). This was further wrapped in tarred hemp and an 18-strand helical sheath of iron wires (Huston, 2020). Now, there are over 400 submarine cables globally using optical fibre to carry digital data, which includes telephony, Internet and private data traffic.

Bandwidth pricing is the norm only because of tradition. For decades, the consortium model of cable ownership and operation prevailed. This meant that capacity pricing of the cable was determined by the consortium to preserve the market value of the cable. It led to rationing and price-fixing where the capacity of the cable was released into the market in small increments,

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ensuring that demand always exceeded available capacity over the lifetime of the cable, and cable prices remained buoyant.

Some cables are now funded by governments (e.g. two thirds of the cost of the Coral Sea Cable to PNG and the Solomon Islands was funded by Australia), international development organisations (e.g. Cook Islands, as noted above) and private companies (e.g. Google).

Wholesale bandwidth pricing from the era of circuit-switched traffic need not apply to the current era where everything is carried as digital data and capacity is abundant. Instead of charging for bits per second (throughput or bandwidth), charge for bytes (traffic). Since data is growing fast, the unit price of traffic can fall, which stimulates further growth – a virtuous circle of price reductions and demand growth.

Counting bytes takes less effort than tracking the 95th percentile and may be fairer (Wikipedia, n.d.):

> Critics of the 95th percentile billing method usually advocate the use of a flat rate system or using the average throughput rather than the 95th percentile. Both those methods favour heavy users (who have interest in advocating for changes to billing method). Other critics call for billing per byte of data transferred, which is considered most accurate and fair.

None of the major cloud services charge for bandwidth. Microsoft's Azure, Google and Amazon Web Services charge many other ways, including for traffic (Azure).

Uncertainty for ACL's wholesale customers would be reduced with traffic pricing. Purchasing bandwidth is not easy. With bandwidth pricing, wholesale customers have to forecast the number of customers, the mix of promised speeds, set contention ratios to throttle demand, and then round-up purchased capacity to what is required by the capacity steps on the wholesale rate card.

Traffic pricing is easy. Operators only pay for what they use – just like any utility.[v] With traffic pricing, they have every incentive to stimulate demand — every byte is profitable. There is no cost uncertainty. They do not have to target fill ratios for purchased bandwidth.

However, there is initial revenue uncertainty for ACL. With bandwidth pricing, if it sells 1G, the revenue is certain, whether it is used or not. Once the initial uncertainty is overcome, demand could drop due to, say, a pandemic. But, while ACL's revenues would take an automatic hit with traffic pricing, under bandwidth pricing capacity purchases would be cut.

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Conclusion

The abundance of capacity that comes with an international submarine cable is a necessary but not a sufficient condition for accelerated social and economic development. If the price structure remains the same as for existing satellite capacity, nothing much will change. In particular, it is important to see the level of retail competition enhanced so that the cheaper cost of international connectivity is passed on to end users.

The proposed adoption of wholesale traffic pricing will stimulate both demand and enable new retail competition.

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Endnotes

[i] An anonymous referee suggested the inclusion of a cost model. Such details are included in a comprehensive report done for another new cable in the Solomon Islands (de Ridder, 2020).

[ii] In Australia, the NBN made the mistake of using connectivity virtual circuits (CVCs, which look like bandwidth sold as leased lines) instead of traffic pricing: *"CVCs can be used as proxies for usage charging"* [p. 103, NBN Co Corporate Plan, December 2010 – no longer available online]. This had the effect of introducing artificial congestion (de Ridder, 2017) where none should exist and has been a major irritation for its customers.

[iii] In September 2015 (de Ridder, 2015), Optus charged A$125 pm for unlimited data over an NBN 100/40 line. The implicit cost of data was 45 cents/GB for downloads of 100 GB pm (and higher for lower volume). The best fit based on 100/40 plans that had data caps was $80 + 5 cents/GB, so that 100G would cost just $85 versus the $125 charged by Optus.

[iv] For example (de Ridder, 2014), when WhatsApp announced in Barcelona in February 2014 that it would offer voice services as well as text, the different comments from two multi-national carriers on the expected impact are instructive:

- The CEO of Millicom, which started in Sweden and operates mobile services under the Tigo brand in Africa and Latin America, begged WhatsApp to "*take it easy — 70% of our revenues come from voice*".
- But the CEO of Tele2, which also started in Sweden and operates mainly in Europe, said: "*Customers get voice and SMS for free. Sorry Mr WhatsApp, but it's free in the Tele2 world*". Tele2 saw the future and started charging for data in order to hitch its revenues to the growth in data and insulate itself from revenue losses due to OTT services.

[v] When Bob James and I developed traffic pricing for a broadband access network, we dubbed it the "5th Pipe" into the home — following the electricity, gas, water and sewage utilities.

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A Compact 38 GHz Millimetre-Wave MIMO Antenna Array for 5G Mobile Systems

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Abstract: This paper presents the design of a compact 2x2 microstrip antenna array of size 11.9x15.3 mm² operating at the mm-wave region of 38 GHz. We achieved a high gain of 14.58 dB, a return loss of -17.7 dB, and a wide impedance bandwidth of 500 MHz. This antenna is duplicated twelve times around an angle of 30° forming a low-profile dodecagon. Each sector can cover a beam of 58° to obtain 12 beams covering the 360 degrees. When compared with implemented antenna designs in the literature that target similar features of compact size and low profile at the desired 5G frequency of 38 GHz, our design had a noticeable reduction in size with an increased gain. Our designed antenna is suited for MIMO beamforming, or switched beam technology applications in mobile wireless systems that include miniaturized base stations or moving network systems, such as mobile hotspots or vehicular networks and related elements.

Keywords: 5G, mmWave, MIMO, compact antenna, antenna array

Introduction

Recent technology trends demonstrate that wireless and mobile communications technologies are blooming at a very rapid rate. It is believed that 5G wireless systems will have greatly enhanced performance reflected in data rates and channel capacity (Mattisson, 2018). Enablers of these high performance systems are contemporary design techniques and principles such as: millimetre-wave (mmWave) technology, massive multiple-input-multiple-output, and sophisticated modulation and coding schemes (Sahoo *et al.*, 2019). Due to limited availability of frequency spectrum resources and propagation challenges

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(Rappaport *et al.*, 2017) at the newly offered frequency bands, efficient utilization of these bands will require deployment of new configurations of multi-antenna systems incorporating beamforming or an antenna array with switched multibeams in these 5G systems. In addition, various everyday systems with drastically different technical requirements are being redesigned to incorporate 5G wireless systems as the primary means for functionality. As such, these include the general Internet of Things (IoT), where billions of devices will be connected and operated relying on wireless 5G systems. Among these various systems, of special importance, are moving network (MN) systems for 5G vehicular communications, that will include applications such as mobile hotspots (Kim *et al.*, 2019; Sahoo *et al.*, 2019). In addition, it is anticipated that within these MN 5G systems, transportation traffic communications will be delivered in point-to-multipoint topologies (Hong *et al.*, 2017; Muirhead, Imran & Arshad, 2016; Wu *et al.*, 2018).

In order to achieve these special-purpose communications topologies, several techniques have been employed. The most prevalent one is spatial or frequency diversity in conjunction with a compact MIMO antenna array. Alternately, this topology is accomplished utilizing multi-beam antenna arrays employed in forming a desired number of concurrent or dynamic switchable but autonomous high-gain directive beams (Hong *et al.*, 2017; Muirhead, Imran & Arshad, 2016; Wu *et al.*, 2018). However, these applications with special communications topologies require compact low-profile multi-beam antenna arrays with multi-feeding ports for use in this context. Thus, the demand for diverse types of advanced antennas with high-performance designs is increasing exponentially in a similar fashion to the accompanying circuits. However, it is often difficult to meet stringent design requirements on bandwidth, radiation pattern, compact size, and cost of the 5G mobile communications networks with most conventional techniques (Yaacoub, Husseini & Ghaziri, 2016). An antenna of the microstrip patch antenna type (Fadamiro *et al.*, 2019; Al Issa, Khraisat & Alghazo, 2020) can have several merits including a low-profile structure, moderate or high gain, high efficiency, low cost, easy fabrication, in addition to robustness. In recent years, for 5G mobile communications, a few researchers have proposed a number of assorted antenna designs. However, the design intricacy such as large size (Al-Tarifi, Sharawi & Shamim, 2018) and ramification accompanied by low antenna gain and low efficiency are a principal impediment affiliated with them (Verma *et al.*, 2016).

We review some of the compact designs that have been put forward recently in the related literature. The authors in (Verma *et al.*, 2016) have presented a small microstrip patch antenna that was designed for 5G communication systems operating at 10.15 GHz that has a size of 10.2 mm by 7 mm with a narrow long rectangular slot. The used substrate is FR4, which has a dielectric constant of 4.4 and a thickness of 1.6 mm. The antenna is fed using

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microstrip edge feeding with a lumped port. This antenna achieved a moderate gain of 4.46 dB with an omnidirectional radiation pattern and resonated at 10.15 GHz with a return loss of -18.27 dB with a bandwidth of 400 Hz. In (Ali, Haraz & Alshebeili, 2016), a Dual-Band printed slot antenna was designed for 5G wireless communication systems that resonates at 28/38 GHz using an elliptical patch with an elliptical slot using a proximity feeding technique on the other side of the substrate. The feed line also has a slot in it, which is rectangular in shape. The substrate used has a dielectric constant of 2.2 and a thickness of 0.127 mm. This antenna achieved a return loss of -45 dB at 28 GHz and -22 dB at 38 GHz. At 28 GHz, the gain is 3.63 with a relatively flat pattern, and 4.45 dB at 38 GHz, also with a relatively flat pattern. A compact dual-band antenna array for millimetre massive MIMO applications was designed in (Ali & Sebak, 2016). This antenna array resonates at 28/38 GHz. Each array consists of eight elements designed using 1-to-2 Wilkinson Power Divider. For massive MIMO applications, a total of twelve arrays are mounted around a cylinder achieving a beam scanning of around 40° at 28 GHz and 30° at 38 GHz. Two substrates were used in the design; the first low permittivity substrate (2.2) has the elliptical patches etched onto it, while the second one has a high permittivity substrate (10.2) with the feeding network etched onto it, thus eliminating any radiation interference caused by the feeding network, as there is a ground plane between the feeding network and the arrays separating their radiations. At 28 GHz, the return loss is about -18 dB, and the gain is 12.07 dB; while at 38 GHz the return loss is -28 dB and the gain is 13.46 dB. The size of each antenna array is 13×20 mm, thus giving a diameter for the ellipse of 50 mm. In (Chen & Zhang, 2013), the antenna design approach uses standard PCB technology on a FR4 substrate (dielectric constant = 4.4). The microstrip grid array is printed directly on the substrate. The antenna has a size of 15×15 where the design achieved an impedance bandwidth of 7.16 GHz, and a realized gain of 12.66 dBi at 29.2 GHz. The printed array consists of eight rectangular meshes. Each rectangle is excited from both sides, and thus radiates at two frequencies; the long side operates as a trans-mission line, while the short side is responsible for both the transmission lines and the radiating element.

Here, in this paper, we present a novel design of a compact and low-profile antenna that operates at a selected popular millimetre-wave frequency of 38 GHz that meets the requirements of 5G cellular systems, with special interest for applications of MN systems and miniature base stations or access points. This compact design was achieved through the use of a compact 2 2 microstrip antenna array of size 11.9×15.3 mm² operating at 38 GHz. In spite of the fact that the antenna is small and compact, it has relatively high performance, where we have achieved a high gain of 14.58 dB, a return loss of -17.7 dB, and a wide impedance bandwidth of 500 MHz. This microstrip antenna array was duplicated twelve

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times around an angle of 30°forming a *dodecagon*. With a total of 48 antenna elements, many challenges arose to overcome the obstacles of millimetre-waves. Utilizing the High Frequency Structured Simulator (HFSS) software, the antenna design simulation and optimization was performed. This design builds on the previously mentioned designs in its compact size when compared with the design in (Ali & Sebak, 2016). However, our design achieved better values in terms of the gain and return loss when compared to the designs discussed above. In the following sections, we describe the details of the design of the MIMO antenna array and its aspects, in addition to obtained results for verification of design parameters and requirements.

Design of the MIMO Antenna Array

In designing an antenna array, the overall results are directly linked to the design of the single element. The patch shape that was chosen held various critical points to keep in mind: return-loss, gain, bandwidth, and design complexity. Working on a design for the desired high frequency range, the decision was to choose a rectangular shape, which held high return loss values, high gain values, and high bandwidth, in addition to having moderate design complexity relative to other shapes. In other words, if a single element antenna has a high gain, narrow bandwidth, and high directivity, an array consisting of duplicates of that element achieves results that are directly dependent on that of the single element. Therefore, a single element was designed and optimized to achieve the best results, then duplicated into a number of arrays. All microstrip antennas consist of at least three layers – where the first layer is a ground plane that simply is a reference to the antenna, above which is the substrate mounted directly between the other two layers, and the top most layer is the microstrip patch. This layer is responsible for radiation to transmit or receive signals. Between the top and bottom layers comes the substrate. The substrate has a thickness that separates the two other layers, and holds the qualities that directly affect the fringing fields.

The substrate

The substrate holds two key parameters: the dielectric constant, and the thickness. In general, as the thickness increases, the resonant frequency increases and the bandwidth decreases. Furthermore, as the thickness of the substrate increases, the fringing field increases, which leads to a decrease in the resonant frequency and an improvement on the return-loss and bandwidth. The dielectric constant defines the amount of energy a material can store in an electric field: increasing the dielectric constant to a point leads to a less efficient and smaller bandwidth radiating antenna. Since the substrate has the ground plane on the opposite side of the antenna, width and length of the substrate are equal to those of the ground. Due to desired design criteria in target applications, a high performance and

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supportive substrate is to be implemented as the second layer. This will have a pronounced effect on the characteristics of the antenna, especially on the fringing fields, which leads to either improper or beneficial proper radiation. It has to be taken into account that, as both substrate thickness and permittivity change, the radiation behaviour of the fringing fields will be affected (Mishra, Kuchhal & Kumar, 2015), as well as the bandwidth and the efficiency. With a low dielectric constant and low dispersion, Rogers RT/Duroid 5880 (Rogers Corporation, 2018) was selected as the most suitable substrate for its superior performance in preserving the efficiency, and not including any higher modes which would hamper radiation.

The effective dielectric constant

The effective dielectric constant links the dielectric constant to the width and the ratio of width to height of the dielectric constant. The following equation can be used to calculate it:

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}[1 + 12\frac{h}{w}]^{1/2} \quad (1)$$

Substituting in (1) yields $\varepsilon_{eff} = 2.0918$.

The length

The length of the antenna is a parameter that determines the operating frequency when excited. In general, the length is usually about $\lambda/2$; where $\lambda = c/f$. Using the equation below, the exact length can be found as follows:

$$L_{eff} = \frac{C_0}{2f_r\sqrt{\varepsilon_{\text{eff}}}} - 2\Delta L \quad (2)$$

Note that the length should be slightly less than a half wavelength. But, due to the fringing effect, it looks physically greater in size, and the antenna's length must be increased by an amount of ΔL, as the equation below shows (Samarthay, Pundir & Lal, 2014):

$$\Delta L = 0.412\frac{(\varepsilon_{eff}+0.3)(\frac{w}{h}+0.264)}{(\varepsilon_{eff}-0.258)(\frac{w}{h}+0.8)} \quad (3)$$

Therefore, the length is now equal to the difference between the two equations above, (2) and (3), as follows:

$$L = \frac{C_0}{2f_r\sqrt{\varepsilon_{\text{eff}}}} - 2\Delta L - 0.412\frac{(\varepsilon_{eff}+0.3)(\frac{w}{h}+0.264)}{(\varepsilon_{eff}-0.258)(\frac{w}{h}+0.8)} \quad (4)$$

After the length is found to be equal to 3.1206 mm, the next step is to choose a proper excitation point.

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The width

The width plays a direct role in bandwidth and return loss: as the width of the microstrip antenna increases, the bandwidth and the return loss increase. However, continuing to increase the width will lead to a point beyond which the bandwidth would be drastically decreased and cause a deviation in the resonance frequency as well (Milligan, 2005). With that in mind, below is the equation used to calculate the width:

$$W = \frac{C_0}{2f_r}\sqrt{\frac{2}{\varepsilon_r+1}} \quad (5)$$

Using (5), the width can be found as W= 2 5956 mm.

The feeding

Our design targets an impedance value of 50 Ω. Since Z=V/I, and the current increases around the centre, the input impedance is greatest at the edges and least at the centre. There are a number of methods to achieve matched input impedance, including aperture couple feeding, coaxial feeding, and inset feeding. In inset feeding, manufacturing will be simpler when compared to other techniques, as well as the size of the overall antenna will not be greatly affected. When the feed is placed directly to the edge of the patch, this gives rise to high input impedance. Therefore, the Inset Feeding method is used in order to minimize the input impedance, where the inset has to be modified by bringing it more towards the centre. The gap on either side of the microstrip line equals its width. This method is useful because it can be directly printed to the antenna board, and where the input impedance can be decreased up to 50%. The position where the inset feed point should be inserted can be found by calculating Z_0.

$$Z_0 = R_{in} * cos^2\left(\frac{\pi}{L_p} - d\right) \quad (6)$$

Moreover, varying the inset length would affect the performance as well, but the inset gap has wider effect on the parameters.

Substrate and ground size

The substrate and ground size affect the efficiency and the bandwidth, as well as the size of the microstrip antenna. The substrate itself has an effect on miniaturization as well as broadbanding the antenna. Furthermore, the ground plane can be used to improve the pattern symmetry, as it can alter the far field pattern shape. In addition, the ground plane also works to avoid and absorb reflections off the ends of the model (Milligan, 2005). With

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that in mind, the size of the substrate and the ground plane must be greater than that of the patch antenna, and is calculated using the equations below:

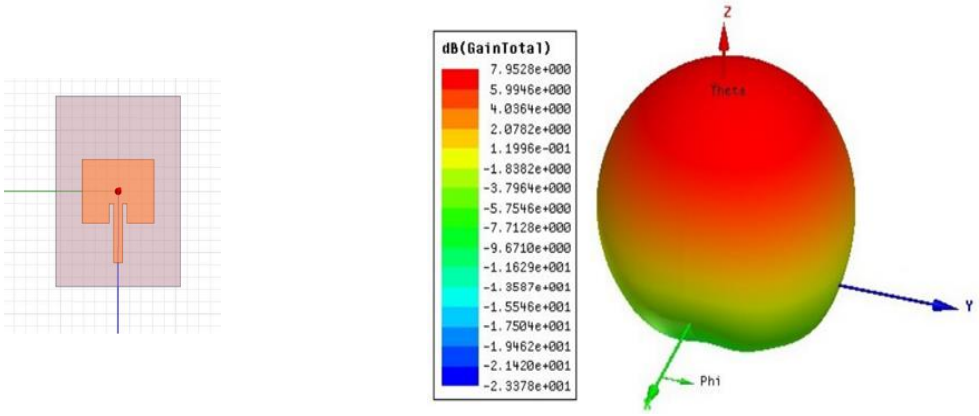
$$L_g = 6h + L \tag{7}$$

$$W_g = 6h + W \tag{8}$$

Both the ground plane and the substrate sizes can be found using equations (7) and (8).

Single element results

A design was implemented to verify the integrity of the calculations. Figure 1(a) shows the antenna modelled using the High Frequency Structured Simulator (HFSS) software. For the final antenna design to achieve better results, each variable in the single element design must be optimized. This allows for tuning the deviation in the operating frequency, maximized gain, return loss, and optimized radiation pattern. In order to justify the integrity of the optimized single element results, all characteristics of the antenna will be discussed. a) The resulting gain is 7.95 dB for the optimized single element, which demonstrates its efficient ability to radiate as desired, or, in other words, how well it converts input power into radiating waves heading in a specified direction. Furthermore, the radiation pattern shows no side lobes. Figure 1(b) shows the gain of the single element. b) The achieved return loss was -29.18 dB. This high value of return loss is very desirable and is evidence of the high efficiency of this antenna design, since it is commonly known that this value should be higher than -10 dB in an effective antenna design. Figure 2 shows the single element return loss (in dB) plotted versus frequency.



(a) **(b)**

Figure 1. Single Element Antenna (a) Shape (b) 3D Radiation Pattern Showing the Gain.

Array

In this design, the number of antennas was chosen in such a way as to get the optimal desired target parameters without sacrificing the compact size and low profile of the overall

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antenna. This is because, in an antenna array, the number of antenna elements plays a direct role in the overall performance of the antenna. Using four elements (2×2), the size remained relatively small, while the gain, return loss, and bandwidth greatly improved. Although using sixteen elements (4×4) achieved better gain and return loss, it caused the antenna to be highly directive, therefore having very narrow beam width.

With the single element carrying the optimal characteristics to meet the requirements, it was ready to be duplicated into an array. Each array consisted of four elements with an orientation to favour the beam width, gain, return loss, and size. Pairing too many elements horizontally results in higher gain and return loss, but decreases the beam width drastically, which causes some areas to be unreachable by the antenna. Therefore, the number of antennas mounted horizontally used is two. For vertical elements, as the number of elements increases, the vertical beam width will be decreased drastically. Furthermore, the size of the antenna also increases greatly, as the feedline is directed vertically and requires spacing between elements. Considering the facts above, the number of elements mounted vertically chosen is two elements. Figure 3 shows the design of the (2×2) patch antenna array. Note that the feeding line is positioned to the side of the array, and excited with a lumped port mounted vertically with respect to the substrate of the antenna. This ensures that the design maintains its low profile after the duplication of the elements. Each antenna element has an input impedance of 50Ω. To connect two antenna elements with minimal losses, the two antennas need to be matched using a quarter-wave transformer and a power divider. The power divider, which has a characteristic impedance of 100Ω, is used to ensure that the power delivered to each element is equal.

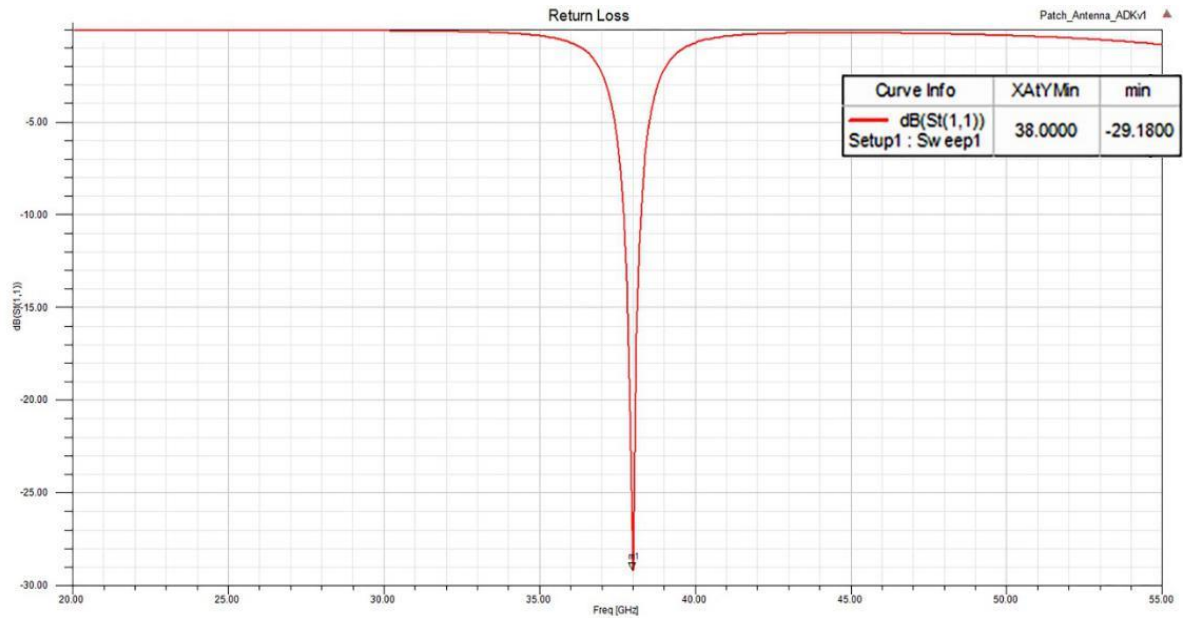

Figure 2. Return Loss of the Single Element Antenna.

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This power divider can be of any length, including zero length. However, the quarter-wave transformer, used to match the two characteristic impedances, has to exist to match the elements. As seen in the figure above, the quarter-wave transformer's impedance is calculated using $Z_0 = \sqrt{50 \times 100}$. Hence, to achieve a microstrip line with a characteristic impedance of 70.7Ω, the width of the line can be calculated using the two equations (9) and (10) (Milligan, 2005):

$$Z = \frac{Z_0}{2\pi\sqrt{2(1+\varepsilon_r)}} \ln\left(1 + \frac{4h}{w_{eff}}\left(\frac{14+\frac{8}{\varepsilon_r}}{11} + \frac{4h}{w_{eff}} + \sqrt{\frac{14+\frac{8}{\varepsilon_r}}{11} + \pi^2 \frac{1+\frac{1}{\varepsilon_r}}{2}}\right)\right) \quad (9)$$

where

$$w_{eff} = w + t\frac{1+\frac{1}{\varepsilon_r}}{2\pi}\left(1 + \ln\left(\frac{4}{\sqrt{\frac{t^2}{h} + \left(\frac{1}{\pi\frac{w}{t}+1.1}\right)^2}}\right)\right) \quad (10)$$

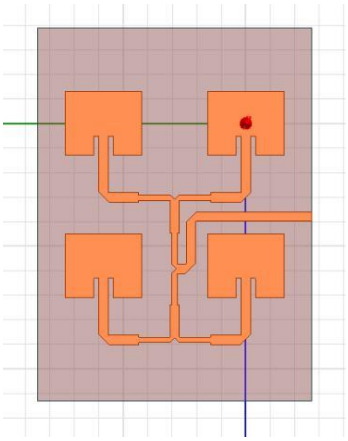

Figure 3. The Proposed 2 × 2 Array.

To reduce power losses, all the 90° corners and all the T-junctions in the feeding network were cut into triangular shape using the method of Mitre Compensation. The following calculations were used to calculate each triangular parameter (Milligan, 2005):

$$x = 0.52 + 0.65 \exp(-1.35\ w/h) \quad (11)$$

All elements on each face were connected to each other using the methodology discussed above. Therefore, to connect the four elements, three quarter-wave transformers were used to match their characteristic impedances.

To ensure that best possible values are achieved using these four element combinations, both the vertical and horizontal spacing between the elements were varied and studied. Table 1 depicts a comparison of the gain, return loss, and operating frequency when varying the spacing. By studying the values in Table 1, the spacing was chosen to favour the gain and the return loss. Therefore, the optimization concluded with a spacing of 6 mm horizontally and 6.5 mm vertically. This also ensures that the overall size of the antenna remains compact.

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Table 1. Optimization of Element Spacing at Operating Frequency (38 GHz)

Vertical Space	Horizontal Space	Return Loss	Gain
5.5	5.5	-16.94	13.65
6.0	5.5	-22.48	13.76
6.5	5.5	-24.67	13.54
7.0	5.5	-16.77	13.22
7.5	5.5	-15.26	12.90
8.0	5.5	-15.22	12.67
5.5	6.0	-17.51	13.94
6.0	6.0	-25.05	13.65
6.5	**6.0**	**-25.20**	**13.70**
7.0	6.0	-18.29	13.40
7.5	6.0	-17.46	13.13
8.0	6.0	-0.61	12.94
5.5	6.5	-17.31	14.08
6.0	6.5	-26.29	14.04
6.5	6.5	-22.97	13.81
7.0	6.5	-18.04	13.56
7.5	6.5	-18.49	13.36
8.0	6.5	-22.61	13.18
5.5	7.0	-0.61	8.76
6.0	7.0	-21.73	14.09
6.5	7.0	-18.54	13.90
7.0	7.0	-17.49	12.72

Final Antenna Design

The final complete 5G antenna must have multiple excitation points to adhere to the antenna design requirements of MIMO technology. In order to maintain symmetry around the antenna, the antenna must take the shape of either a cylinder or a polygon with multiples of four sides. As the substrate used is not flexible, the proposed design used a polygon. The number of sides used is twelve (dodecagon). This invokes sectoring capabilities into the antenna design, which helps isolate users (in a base station application context) during communication, or multi directional reception beams in a VE. Furthermore, with the use of multiple inputs, the antenna could benefit from beamforming, which helps in delivering and receiving stronger signals when obstacles stand between the two endpoints, as mm-waves have very weak propagation and can be absorbed very easily by obstacles in the environment. To integrate a final design, a total of twelve antenna arrays were used.

Each array is angled at 30° with respect to its adjacent array. This way of mounting the antennas results in a dodecagon (twelve-sided polygon). Simulations of the final antenna design were carried out using HFSS. The final design consisted of 48 antenna elements, divided into 12 arrays such that each array consists of four elements in a 2×2 array configuration. The substrate, Rogers RT/Duroid 5880, is very thin, with a thickness of 0.127

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mm. Each antenna element has a length of 3.12 mm, and a width of 2.6 mm. The feeding gap was cut at 0.793 mm deep along the length of the antenna. The width of the microstrip feeding line is 0.391 mm, leaving a gap of length 0.196 mm at each side of the line. Furthermore, the feeding line is 2.405 mm long. In the 2×2 array, the separation between the two elements horizontally measured from centre to centre is 6.5 mm, which translates to 3.38 mm from edge to edge. The vertical separation used is 6 mm from centre to centre: that is, 3.4 mm from edge to edge. Three quarter-wave transformers were used to connect the array; each has a length of 2.924 mm and a width of 0.222 mm. Also, a total of nine triangles were cut to reduce power losses. All triangles are equilateral, with side length of 0.26174 mm at the quarter-wave transformers, and 0.26174 mm at the other 50Ω lines.

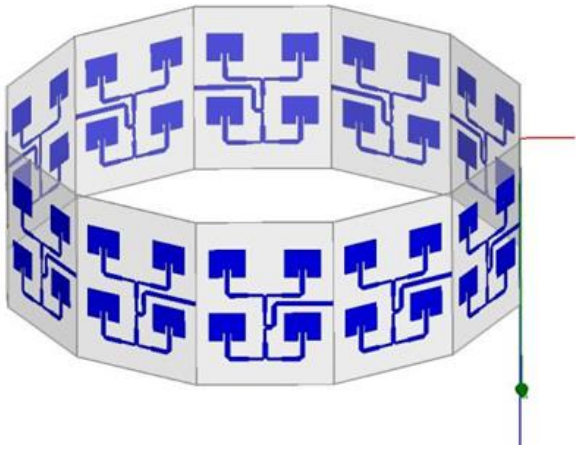

Figure 4. The Final Antenna Design.

The total size of each array is 15.392 mm long by 11.9 mm wide and 0.127 mm thick. Figure 4 depicts the design of the final antenna prototype. With each side of 11.9 mm, the circumcircle diameter of the polygon is 45.978 mm, and the inner circle diameter is 44.411 mm. The total area of the polygon is 1330.203 mm² (counting the gap in the middle as part of the antenna). Moreover, the antenna maintains its low profile by the use of the microstrip feeding technique.

Simulation Results of the MIMO Antenna Array

The achieved return loss by our proposed design is depicted in Figure 5. It is evident in Figure 5 that the lowest point in the graph occurs at a frequency of 38.1141 GHz. The return loss at that frequency is -17.7122 dB; this value translates to an antenna that radiates most of its input power at that frequency. In addition, in this graph the -3 dB point occurs first at a frequency of 37.2730 GHz and crosses it again at 38.7390 GHz. Thus, the bandwidth of this antenna is 1.4660 GHz. In addition to that, the 10 dB bandwidth of the antenna is 0.509 GHz. Figure 6 shows the 3D gain polar plot, where the figure shows the gain of the antenna in the direction of the excited port is 14.358 dB. In addition, there exist side lobes with a low

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gain of about 5 dB. This pattern can be rotated as desired in increments of 30°along θ-axis. The gain values are the same for all sides. Since there are twelve sides, each with a coverage range of about 60°, this enables the antenna to scan 360°with minimal overlapping and dead zones. Figure 7 shows the return loss of all mutual terms when a single side is excited. This figure demonstrates the crucial isolation between elements, where the self-term starts at 0 dB and quickly drops below -10 dB around the operating frequency, then rises back to 0 dB. All other mutual terms have very low return loss values that do not affect the radiation of the antenna. In HFSS, realized gain value differs from traditional gain described in this paper; this is due to the fact that the realized gain accounts for all losses that might affect the obtained result. Hence, when plotting the sector covered by each side, it is fair to account for all losses. Figure 8 is a plot of the azimuth plane realized gain when the antenna face facing 0° is excited. Figure 8 shows a beam width of 58°.

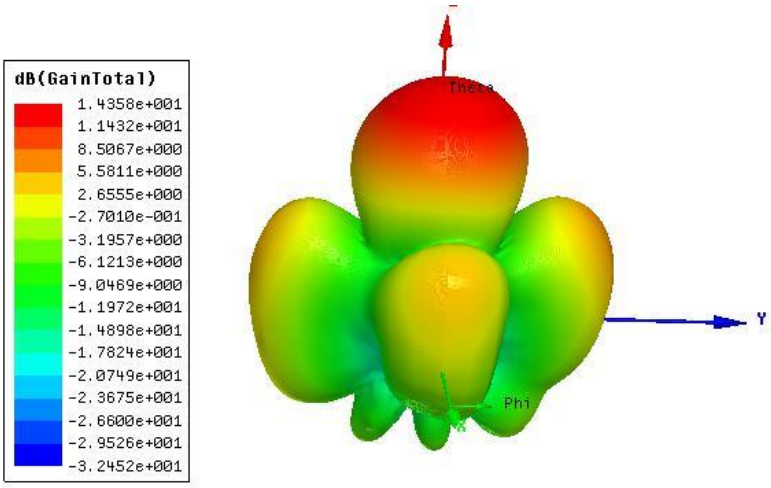

Figure 5. 3D Gain Polar Plot.

With each antenna array angled at 30°, this ensures that all areas around the antenna are covered. The figure also shows two side lobes, each with a gain of less than 2 dB, which is unlikely to interfere with any transmission or reception of signals. To show the maximum number of sectors and the coverage range, all arrays were excited individually and overlaid into the same plot, as depicted in Figure 9, which shows all the sectors. The coverage of the 360 degrees is achieved as the 12 faces are excited individually. As seen above, each sector can cover a beam of 58° to end up with 12 beams covering the 360 degrees. Despite the fact that some areas overlap between two adjacent sectors, the methodology of the arrayed antenna achieved the goal of transmitting and receiving signals in all directions.

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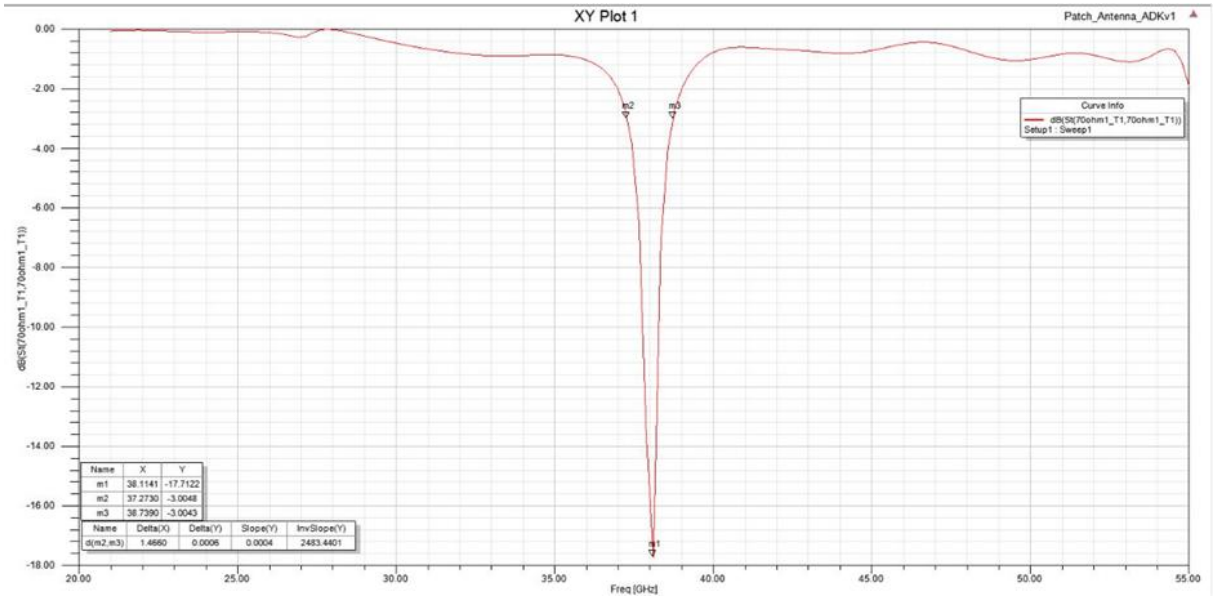

Figure 6. The Return Loss.

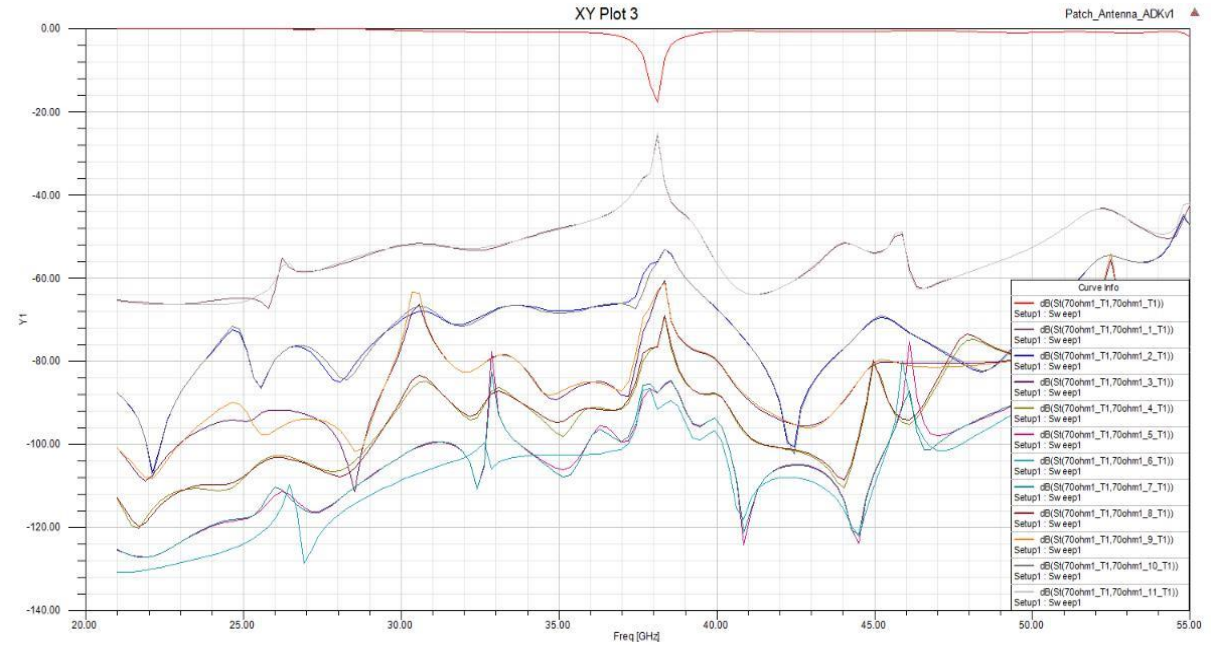

Figure 7. Return Loss Showing Self-Terms and Mutual-Terms.

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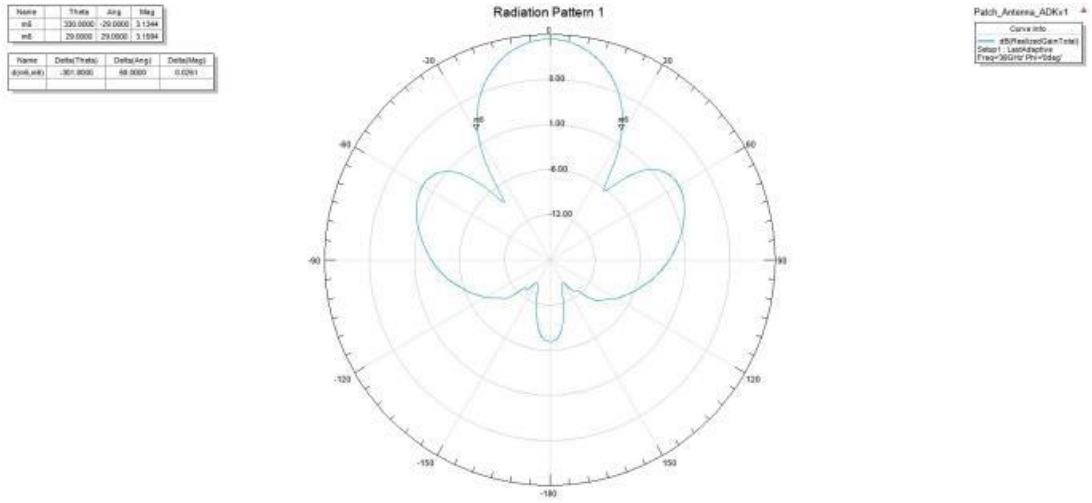

Figure 8. Realized Gain in Azimuth Plane.

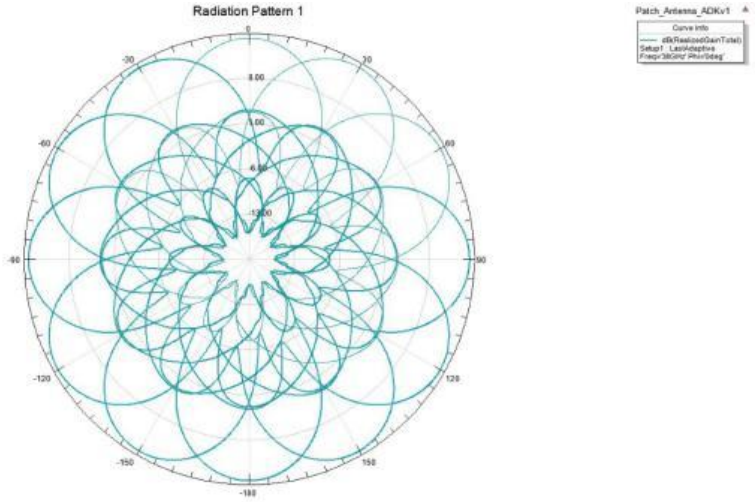

Figure 9. Azimuth Plane Showing All Sectors.

Conclusion

In this paper, the structure of a compact and low-profile efficient high gain sectoring antenna array operating at a mmWave frequency of 38 GHz was presented. The design of this compact antenna uses a 2×2 microstrip antenna array of size 11.9×15.3 mm². At this operating frequency of 38 GHz, we achieved a high gain of 14.58 dB, a return loss of -17.7 dB, and a wide impedance bandwidth of 500 MHz. This 2×2 microstrip antenna array is duplicated twelve times around an angle of 30°forming a dodecagon. Each sector can cover a beam of 58° to end up with 12 beams covering the 360 degrees. When compared to antenna designs with a similar purpose in the literature, our design operated at the desired 5G frequency of 38 GHz and had a noticeable reduction in size, in addition to an increase in gain of about 1.5 dB. Our designed antenna is suited to beamforming or switched-beam MIMO technology applications that require compact and low-profile antennas, such as MN systems in 5G vehicular communications.

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Over-The-Top Media in Digital Economy and Society 5.0

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Abstract: Indonesia has entered into global economic development that is based on innovation, communication and technology. This is the first point where it becomes the driving force in economic growth. The Indonesian millennial population, which is creative and innovative, has the potential to increase national economic growth based on the digital economy and aim for Society 5.0. Nowadays, innovation and creativity are the keys to success in economic growth in the globalization era. Those keys are closely related to the intellectual property system. In the globalization era, developed countries are the ones utilizing intellectual property as a driving force for the economy through science, technology, creativity and new innovation. One of the changes in media is the rise of Over-The-Top (OTT) service providers, a media service growing in popularity in the world of telecommunication, government and academia. Given these changes, Indonesia should protect a creator's economic rights over content through implementing regulations to enforce its copyright law and enable the monetization of content. Telecommunications providers should focus more on the content industry.

Keywords: Digital Economy, Innovation, Society 5.0, Technology.

Introduction

By 2019, digital transformation has changed the way of life for millennial communities. For instance, the Japanese government has begun to introduce **Society 5.0,** where digital

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technology is centred on human life; thus, people can enjoy life in a simple manner. In today's digital era, technology and science have grown rapidly. Advances in technology and science have influenced many aspects of human life that have never been imagined before (Ramli, 2018).

In an era of massive data exchanges, economic growth and digital technology development have been supported by global citizens from various backgrounds. Corporations have made many efforts in the use of information technology as a competitive advantage. This is because at the heart of company performance is a competitive marketplace; it is mandatory that companies put strategies into practice (Porter, 1985).

Transformation of Information and Communication Technology

Information and communication technology have also shifted the paradigm in the global economy from traditional economic systems that relied on manufacturing towards a digital economy based on information as well as intellectual and scientific creativity, also known as the creative economy (Makarim, 2010).

In this regard, the Internet of Things and Big Data are likely to take over to change human life in the ever-growing future. In the Society 5.0 era, money is no longer the main point; instead, data connects and moves everything. It fills the gap between anything and the infrastructure. In Japan, for example, the projected reduction in population influences the infrastructure for the number of residences.

Life is about a change and transformation. Firstly, in Society 1.0, people conducted themselves in a communal group. In Society 2.0, people understood social order, so that they could engage from one group with another. In Society 3.0, they were able to make groups to find ways to solve their problems; hence, they communicated to make group decisions.

Table 1. The Industrial Revolution

Industry 1.0	Industry 2.0	Industry 3.0	Industry 4.0
1712 Implementations of Mechanical Production Plants	1840 Mass Production based on the Division of Labour and electricity	1971 Automation of Production Processes	1998 Autonomous Machines and Virtual Reality
Through the Introduction of Mechanical Facilities powered by Water and Steam	Through the Introduction of Mass Production based on electrical energy	Electronics, IT and Heavy-Duty Industrial Robots for further Automatic Production	Cyber Physical Systems Internet of Things

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Indonesia has now entered into the industrial era 4.0, as characterised by a society that has engaged in digital technology and information. Society 5.0 is a group that has been able to utilize technology in their daily lives since the Industry 4.0 era.

The current development also affects the industrial world. The term Industrial Revolution 4.0 originates from a continuation of the previous industrial revolutions. The Industrial Revolution 4.0 is a combination of manufacturing industry optimized with the latest internet technology. This revolution is not only initiated by the emergence of certain telecommunications technologies but also by the cooperation of several technologies that create new ways of production. Prior to the Industrial Revolution4.0, there were three previous industrial developments, namely steam engines in the early 19th Century, electricity in the 20th Century and electronic devices, such as computers, in the early 1970s that enabled automation of production (Schmidt *et al.*, 2015).

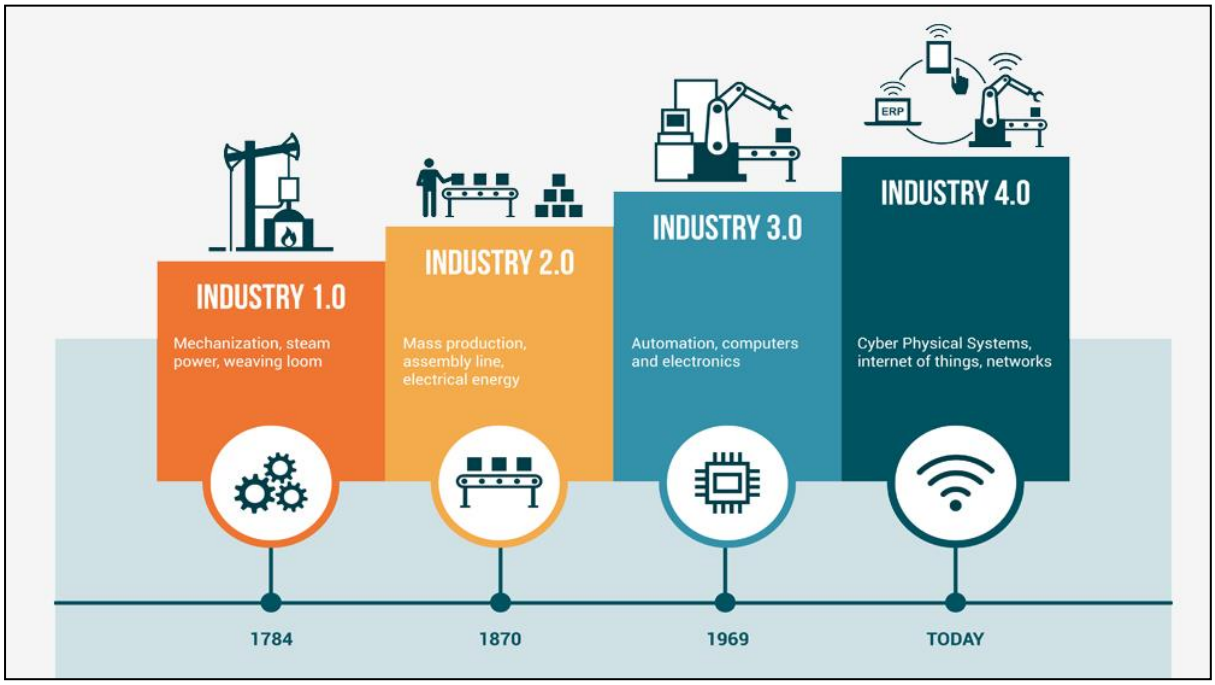

Figure 1. Industry Revolution (Momentum, 2019)

Industrial Revolution 4.0 has a trading model and processes for production. In addition, there is a relation between material production and computer-based processes. Specifically, technology related to the Industrial Revolution 4.0 is the Internet of Things, IT and heavy-duty industrial robots for further automatic production (Cordes & Stacey, 2017).

A challenge for the Industrial Revolution 4.0 arises from intellectual property on digital media, Cyber-Physical Systems and the Internet, specifically the relationship between the Industrial Revolution and Copyright (Samuelson, 1990).

The Industrial Era 4.0 is the technology process of Society 5.0, with advanced technological development in the form of infrastructure that can cause major changes to the work of

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information technology in the field of government or the behaviour of everyday society. Rapid technological developments bring progress to almost all aspects of human life. (Sastrawidjaja, 2002).

Digital Media Changes the Copyright on Intellectual Property

In Society 5.0, human daily problems can be solved by various technologies, such as artificial intelligence. Now, robots and sensors can be used to do the work that is only feasible by means of digital technology-driven processes based on sophisticated big data and the Internet. This can reduce a range of risks, including alleviating accidents in the workplace. Further, it can decrease time duration and even improve work security and productivity.

Digital technology is a "perfect" technology, as it can be freely and easily copied, manipulated and re-edited. Hence, intellectual property is increasingly recognized as the most important intangible asset determining a company's market value (Shettar, 2008).

Copyright infringement may cause losses to companies operating on a larger scale. Hence, there is an urgent need for copyright protection that covers digital content distribution. Information protected by copyright is secured when transformed into a digital form: for example, an article, song, image, or photo distributed through Internet media.

From practices around the world, it is known that copyright protection cannot be guaranteed without law enforcement infrastructure. In general, the legal procedures for copyright law enforcement are governed by national law and are carried out by the national authorities.

However, there are multinational norms or regional instruments from national authorities with regards to the enforcement of intellectual property rights in general, and copyrights in particular. In international scope, due to territorial and procedural costs, most disputes seek alternative mechanisms to achieve resolution.

A digital economy concept is applicable not only to the Internet world but also to global economic impacts on information and communication technologies, aside from the economy in general. It is a new perspective on the development of innovations and technology that impact on the Indonesian economy that ultimately depends on digital technology. E-commerce is defined as the concept of digital economic transactions involving the Internet, the World Wide Web, applications and browsers in transactions that essentially utilize digital technology as an economic transaction (Laudon & Traver, 2017).

The e-commerce sector is the largest contributor to the Indonesian digital economy this year, in which it was predicted to reach 12.2 billion USD, indicating an increase of 94 percent compared to 2015. Further, it is predicted that it will contribute 52.7 billion USD, or more than half of Indonesian digital economic revenue, by 2025. E-commerce is the main driver of digital

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economic growth. There will be huge opportunities in this sector. It includes wireline or wireless communication network (e.g. Internet, intranet, extranets), computers, software, and other related information technologies (Turban *et al.*, 2017).

In addition, information and communication technology also influences a paradigm shift of the global economy from a traditional economic system towards a digital economy. Information, intellectual activities, science, and creativity are also known as the creative economy.

The Indonesian government will encourage the development of digital economic industries and electronic commerce (e-commerce). One of the keys to success in the implementation is information and communication technology (ICT). The ICT implementation can be carefully studied from companies that pioneer the way to succeed in utilizing new digital technologies.

The emergence of Over-The-Top (OTT) Media is as an application service provider for digital Internet media. Telecommunication network operators and Internet Service Providers (ISPs) are the impetus for the rapid advancement of globalization of the economy. Technology advances must continuously strive to reach the international market.

OTT, a media creator through Cyber Broadcasting, is well known as a service that utilizes network infrastructure owned by an operator, yet puts the operator at a disadvantage. An OTT service is an application through the Internet and a content service over the Internet.

OTT service providers are parties who provide, manage, and service activities, either individually or collectively, for other parties. OTT service provision includes the use of OTT services by an individual or business entity. OTT service providers are individuals, communities or business entities. With regards to the object of copyright in OTT, the use of applications with the power of big data and the Copyrights Act is the rule that protects the contents of OTT applications.

E-commerce is an example of the digital economy. It can be defined as the concept of digital economic transactions involving the Internet, the World Wide Web, applications, and browsers in transactions. Basically, it utilizes digital technology as the media in carrying out economic transactions. To take a case in point, a successful e-commerce utilization is Uber. It implements a ride-sharing system that allows someone in need of transportation to seek mobilization options and pay for the request; peer-to-peer facilitates both in the network (Masoud *et al.*, 2017).

The concept of ride-sharing divides the economy into two important elements, namely the availability of offers that have excess capacity and the attitude or willingness to share. As Yochai Benkler said, the sharing economy, in this context, is also called "excess capacity" of various goods or vehicles and services (Calo & Rosenblat, 2017).

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Recommendations

- Indonesia must apply Monetization Technology to protect a creator's Economic Rights to the Copyright Content that is broadcast through Over-The-Top media services, such as YouTube, Netflix, or Spotify. These are platforms that can only survive based on the content availability. These media accommodate content uploaded by users and become part of the substance of commercialized content that is accessible by the public.
- Indonesia should implement regulations that cover the authority of institutions managing copyrights, as well as those in charge of handling information and telecommunications to regulate the implementation of the Copyright Law (Indonesia, 2014) in relation to Content Commercialization by means of OTT media services.
- The Telecommunications Industry needs to focus more on and prioritize the content industry. Enhancing the national commercialization of Copyright Content will have a direct impact on the development of the national Digital Economy that is currently moving towards Society 5.0.

Conclusions

The emergence of e-commerce provides a range of convenience, from buying products without the need to come to the store, selling products without requiring a physical store, ordering food without leaving the house, delivering products, to ordering public transportation by only tapping mobile phones.

By means of the digital platform, all services can easily reach many people in different countries. As a result, it would benefit those living far away from the metropolitan area as digital services can also be of benefit to them. The development and innovation of digital platforms greatly affect efficiency, both in terms of manufacturing and marketing. It certainly requires intelligence to optimize strategies in the digital disruption era.

Digital transformation occurs rapidly. Copyright contents become a critical element and have a high valuation, especially in relation to OTT media services. OTT Media such as YouTube, Netflix, and Spotify are examples of platforms that can only survive based on content availability. A media, in principle, does not create content, rather it accommodates content uploaded by its users to become a part of the substance of the commercialized and publicly accessible content. The international practice places an OTT media service as a party that publishes copyright content. The problem is whether the content is published with the authors' permission. The issue arises as the users uploading the content are not always the creator of the content. It can therefore be concluded that the practice of content commercialization

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through OTT, either directly or indirectly, must continue to protect the exclusive rights, both economic and moral, of the content creators. Thus, those having economic benefit are not only the channel owners, the uploader, and the owners of the OTT platform, but also the creators. This can be conducted by utilizing methods such as monetization technology.

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Energy-Efficient Topology to Enhance the Wireless Sensor Network Lifetime Using Connectivity Control

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Abstract: Wireless sensor networks have attracted much attention because of many applications in the fields of industry, military, medicine, agriculture, and education. In addition, the vast majority of research has been done to expand their applications and improve their efficiency. However, there are still many challenges for increasing the efficiency in different parts of this network. One of the most important parts is to improve the network lifetime in the wireless sensor network. Since the sensor nodes are generally powered by batteries, the most important issue to consider in these types of networks is to reduce the power consumption of the nodes in such a way as to increase the network lifetime to an acceptable level. The contribution of this paper is using topology control, the threshold for the remaining energy in nodes, and two metaheuristic algorithms, namely SA (Simulated Annealing) and VNS (Variable Neighbourhood Search), to increase the energy remaining in the sensors. Moreover, using a low-cost spanning tree, an appropriate connectivity control among nodes is created in the network in order to increase the network lifetime. The results of simulations show that the proposed method improves the sensor lifetime and reduces the energy consumed.

Keywords: Wireless Sensor Network, Connectivity Control, Lifetime, Meta-heuristic Algorithm, Energy Efficient

Introduction

Wireless sensor networks are one of the kinds of wireless ad hoc network that today have many applications in the fields of industry, military, medicine, education etc. These networks consist of tens to thousands of wireless nodes without monitoring (Vecchio & López-Valcarce, 2015),

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which are easily deployed in different environments and have defined specific functions for nodes. One of the advantages of a wireless sensor network is its high development speed due to its simplicity, the low cost of implementation, and automatic configuration. However, because of features such as the poor battery life in sensor nodes, it faces challenges (Yetgin, Cheung, El-Hajjar & Hanzo, 2017). Many studies have been carried out by researchers on the characteristics of this network to improve many of its capabilities. Because of the importance of this network in most areas, it has been decided to find a solution to increase the sensors' lifetime by reducing energy loss.

Many (heuristic and metaheuristic) methods have been proposed to increase the network's lifetime, such as clustering of sensor nodes, connectivity control, or a mobile sink. Energy consumption in wireless sensor nodes has a direct relationship with the network lifetime so that, if the process of energy consumption is reduced in the sensor nodes, it is claimed that the network lifetime increases. One of the methods to increase network lifetime is connectivity control in the wireless sensor network (Zhao, Guo, Wang & Wang, 2015).

In this paper, we are looking to create a spanning tree that can increase the network lifetime. A way to achieve this goal is to use a mobile sink and a spanning tree of the sensor nodes in the network. Sensor nodes send their received data to the base station for analysis and statistical reports by way of one or several sinks. Simulation results show that the network lifetime has improved in this study compared to Zhao *et al.* (2015).

In the first part of the article, the introduction of wireless sensor networks is discussed. In the second part, related works are introduced. In the third part, the proposed method is presented and, in the fourth section, simulation of the proposed method is described. In the final section, the conclusion and future works are discussed.

Related Work

A wireless sensor network is categorized as a wireless ad hoc network, a subject which has attracted a lot of attention in terms of academic and industrial studies in recent years (Zhao, Guo, Wang & Wang, 2015). Despite the many advances made in wireless sensor networks, there are still challenges, including energy consumption, routing, scalability, security, and fault tolerance. Routing and finding the most appropriate path among nodes of a wireless sensor network have many benefits, including connectivity control, increasing throughput, and eventually increasing the network lifetime.

In Liang & Liu (2006), the "maximum lifetime algorithm" has been proposed, where nodes are added with a greedy policy to the routing tree one by one. Furthermore, the proposed algorithm seeks to increase the network lifetime without knowing about the queries and their

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production rates. Only nodes can be added to the routing tree if they are able to increase the network lifetime.

In Heinzelman, Chandrakasan & Balakrishnan (2002), the LEACH algorithm has been described. The algorithm is hierarchical: at one level, it has a number of nodes as head clusters; and, at the next level, the nodes that do not belong to any of the head clusters are members of these clusters. One of the advantages of this method is increased load balancing among all network nodes.

In Tan & Körpeoğlu (2003), two PEDAP and PEDAP-PA protocols are proposed and the goal is to increase the network lifetime and the balanced energy consumption in each node. The results show that the proposed protocols have better performance than LEACH and PEGASIS protocols to increase the network lifetime.

In Gao, Zhang & Das (2010), integer (0-1) linear programming is used to find the optimal mapping among the members. After that, a two-dimensional genetic algorithm is used for optimal routing among members. Finally, a two-phase focused communication protocol is used to support the "maximum value of shortest path" algorithm.

In Zhang & Shen (2008), the problem of balancing energy is formulated as the problem of optimizing the allocation of data transmission by combining the idea of network division based on CORONA and a hybrid routing strategy. The proposed EBDG protocol has better output compared to multicast transmission schemes, direct transfer, and cluster rotation.

In Zhang, Shen, & Tan (2007), they are looking for the load balanced consumption to aggregate the sensor network data. The solution is found by a comparison between data transfer by hop-by-hop routing and direct transfer from the nodes. Thus, two RLN and GCN models are introduced to reduce energy consumption in the network.

In Hua & Yum (2008), the proposed algorithm combines the collected data with the desired routing and presents a smooth approximation function to optimize the problem. As a result, the network lifetime increases by routing and maximizing data aggregation. It also affects network traffic reduction.

In Hao, Wang, Yao, Geng & Chen (2018), a new model is proposed to predict the lifetime of a wireless sensor node on the basis of a Markov model (MPLM). Additionally, TCAMPLM is provided by adjusting the transmit power of sensor nodes to keep energy in the nodes.

In Hou & Zhang (2018), the mobile service computing algorithm is proposed to solve the problem of connectivity control in the wireless sensor network.

In Javadi, Mostafaei, Chowdhurry & Abawajy (2018), a connectivity control algorithm based on a learning automata called LBLATC is proposed. The learning automata chooses the

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appropriate transmission range of nodes to use the reinforcement signal generated by sensor nodes. The simulation results show that the expressed protocol has proper performance.

In Hadikhani, Eslaminejad, Yari & Mahani (2020), an algorithm is presented to improve the lifetime in wireless sensor networks. This algorithm initially detects a dynamic hole, then bypasses the hole, so that the nodes around the hole consume less energy.

In Zhao, Guo, Wang & Wang (2015), by using a greedy policy and dynamic programming, an innovative connectivity control algorithm (MLS) is proposed that use a mobile sink. The purpose of this method is to increase the minimum node energy in the wireless sensor network, which leads to maximizing the network lifetime. This method has better performance in increasing the network lifetime compared to previous methods.

Wang, Gao, Liu, Sangaiah & Kim (2019) presented a method for energy efficient routing. They used a combination of clustering and mobile sink. First, they divided the network into regions. Then, each region chose a cluster based on residual energy and distance of source node. After clustering, all clusters calculate the routing path and select a path with optimal energy consumption.

In Wang, Cao, Li, Kim & Lee (2017), they proposed an energy efficient routing algorithm with mobile sink. During the routing process they clustered the network by particle swarm optimization based on residual energy and position of node.

Bencan, Panpan, Peng & Dong (2020) proposed an algorithm to prevent energy holes and improve load balance in the network. They used an evolutionary game model for mobile sink based on residual energy and energy consumption of each cluster to make a utility function. A cluster that has greater utility value is selected as the new location of the sink.

In Pandiyaraju, Logambigai, Ganapathy & Kannan (2020), a routing protocol based on Intelligent Fuzzy Rules was provided for the agriculture sector. The purpose of their approach was to improve energy efficiency in the routing process to provide information for an irrigation system.

In Yarinezhad (2019), a new routing algorithm was presented which uses a virtual multi-ring shaped infrastructure to advertise the mobile sink position to the network.

Proposed Method

In this paper, we are looking to enhance the network lifetime by using connectivity control of sensor nodes and considering three limits based on the remaining energy of the sensor nodes. In fact, in this network, a certain threshold for local search is obtained and the changes in communications among nodes happen when their energy level reaches this threshold. In the

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following, we use the metaheuristic algorithms, which include variable neighbourhood search (VNS) (Hansen, Mladenović, Todosijević & Hanafi, 2017) and simulated annealing (SA) (Hao *et al.*, 2018), to achieve a spanning tree that maximizes the minimum sensor lifetime. We assume that a number of wireless sensor nodes are located in an environment with a mobile sink. a mobile sink is a mechanical node that move through the network to collect data from other nodes and transfer data to the base station; it is used to save sensor energy for multi-hop communication in transferring data to the base station. Sensor nodes in this research are divided into two categories: anchor sensor nodes and normal sensor nodes. Anchor sensor nodes are nodes close to the path of the mobile sink, and the normal nodes are nodes that are farther away from the path of the mobile sink. The normal nodes send received data from the surrounding environment or their next normal node as single or multiple messages to anchor nodes (Zhao, Guo, Wang & Wang, 2015). The anchor nodes send received data from the surrounding environment, along with the data received from their previous normal nodes, to the mobile sink when it is close to the anchor nodes. This connection creates connectivity between sensor nodes and the mobile sink. We want to create a spanning tree from the wireless sensor nodes with the root at the mobile sink that contains all network nodes. Our objective is to maximize the minimum network lifetime so that the death of the first sensor node occurs later. Figure 1 shows the schematic structure of the proposed algorithm.

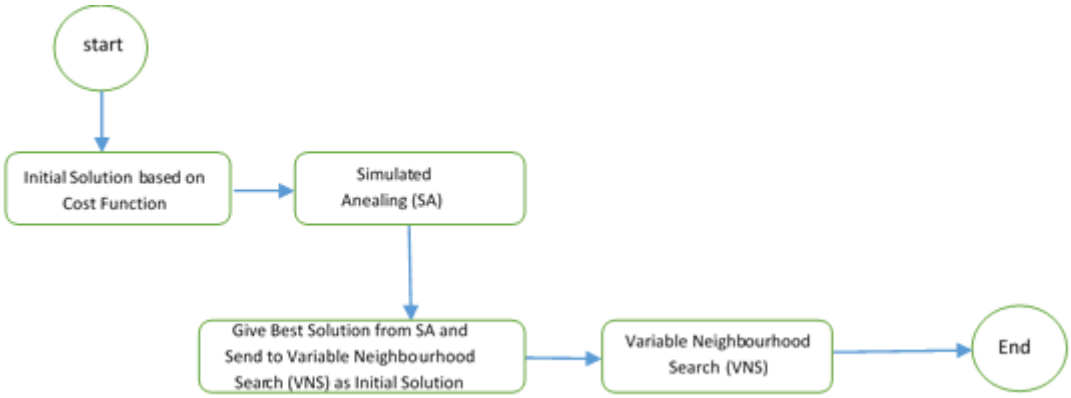

Figure 1: Schematic structure of the proposed algorithm

Energy Consumption Model

Sensor nodes, regardless of what roles they can play in a wireless sensor network, if they have enough energy, they can receive data from their surrounding environment and send the received data to the next node that is closer to the path of the mobile sink, according to the algorithm available in the network. They can also receive data from their neighbours depending on the defined methods in that network, and send the received data along with their data to the next sensor node. Generally, the sensor nodes consume more energy at the time of sending and transmitting the data to the next node. In Heinzelman, Chandrakasan &

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Balakrishnan (2002), , according to the first-order radio model, a cover radius is defined based on the energy required in the free multipath space as follows:

$$E_m = \{(E_{elect} + E_{da} \times l) + (E_{amp} \times l \times d^{\alpha})\} \quad (1)$$

In equation (1), E_m is the energy consumed at the sensor node, and E_{elect} is the energy emission for transmitting and receiving data (J/bit). E_{da} is the energy consumed to aggregate sensor node data (nJ/bit/message) and E_{amp} is the emission of energy for the amplifier (pJ/bit/m²). l is the length of the message and d is the distance of the current node from its neighbour node. The coefficient α is 2 for free-space transmission and 4 for multi-path fading.

Energy consumption in this research is based on equation (1). The most important part of our research is the remaining energy of the nodes. Each sensor node can be a bottleneck to increasing the network lifetime. As a consequence, we choose the connectivity control based on the minimum spanning tree to increase the network lifetime.

Proposed Algorithm

The sensor nodes are randomly distributed in a 1000 metres by 1000 metres environment, for example, and the sink node moves in a predefined path. Each node locally receives its distance from neighbours by using a Hello message. Nodes that are close to the path of the mobile sink are known as anchor nodes and nodes that are farther away from the path of the mobile sink are called non-anchor nodes (normal nodes). Anchor nodes are responsible for sending their data and the data of non-anchor nodes to the mobile sink. The relative load of sensor nodes is based on:

$$l_{(v)} = \frac{(Crx+Ctx(r(v))\times q(v)-Crx)}{e(v)} \quad (2)$$

This is the cost of energy for the remaining energy in the sensor node. In this equation, v indicates a sensor in the network. C_{rx} indicates energy consumption for receiving data at the node. $C_{tx}(r_v)$ is the energy consumption for transferring data from the node to another by considering the distance between them. $q_{(v)}$ indicates the number of child nodes for which the current node is the parent and $e_{(v)}$, expresses the remaining energy of the current node.

Equation 3 shows that the relative load of a node can be alleviated by reducing the number of its descendent nodes or shortening the transmission radius (Zhao, Guo, Wang & Wang, 2015). Then, for minimizing the maximum relative load of the sensor nodes:

$$minimize: \max\{l(v) | \, v \in V\} \quad (3)$$

Thus, nodes that reduce the load of our spanning tree are added to the tree (Figure 2).

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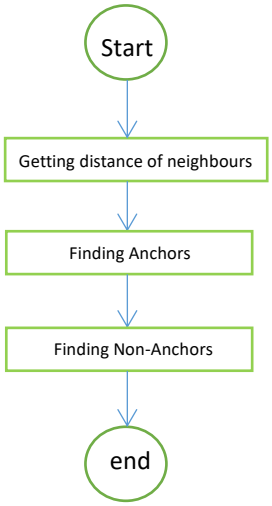

Figure 2. Steps to create spanning tree

Initially, it starts from the root node (the sink).

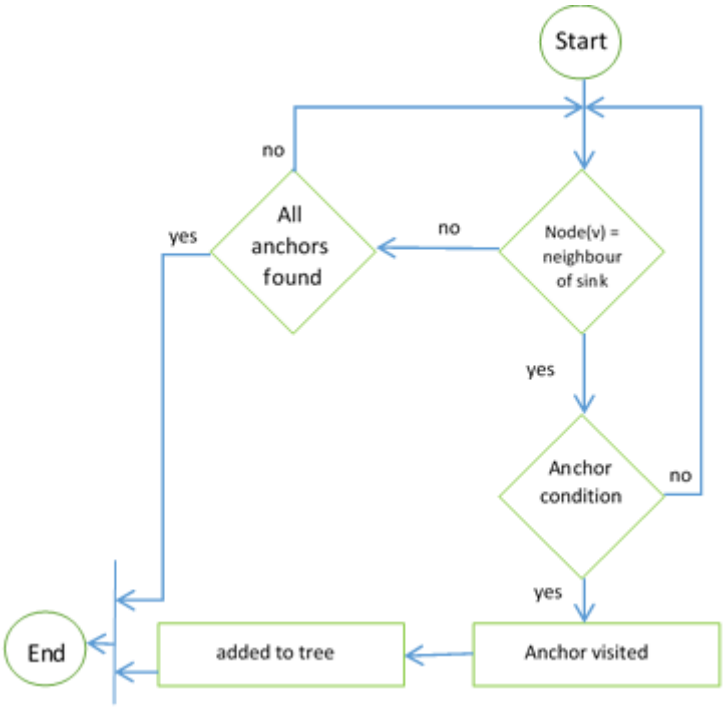

Figure 3. Finding Anchors

As shown in Figure 3, after the anchor nodes are identified and connected to the root node, in the next step, the relative load of neighbour nodes is calculated according to equation (2), if they were not previously members of the spanning tree and their remaining energy has not reached the threshold value (Figure 4). A node that has the lowest relative load (initial selection phase) (Zhao, Guo, Wang & Wang, 2015) is selected as the candidate node. The amount of relative load is obtained on the basis that, if the candidate node is to be attached to the tree, its cost will be its relative load. In the next step (final selection phase), for the nodes that have been selected in the previous step, the loads on candidate nodes in the spanning tree are sorted in ascending order and the largest amount of load is compared with the largest

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amount of load of the other candidate nodes. Then, the lowest amount is added as the selected node to the spanning tree (Figure 5).

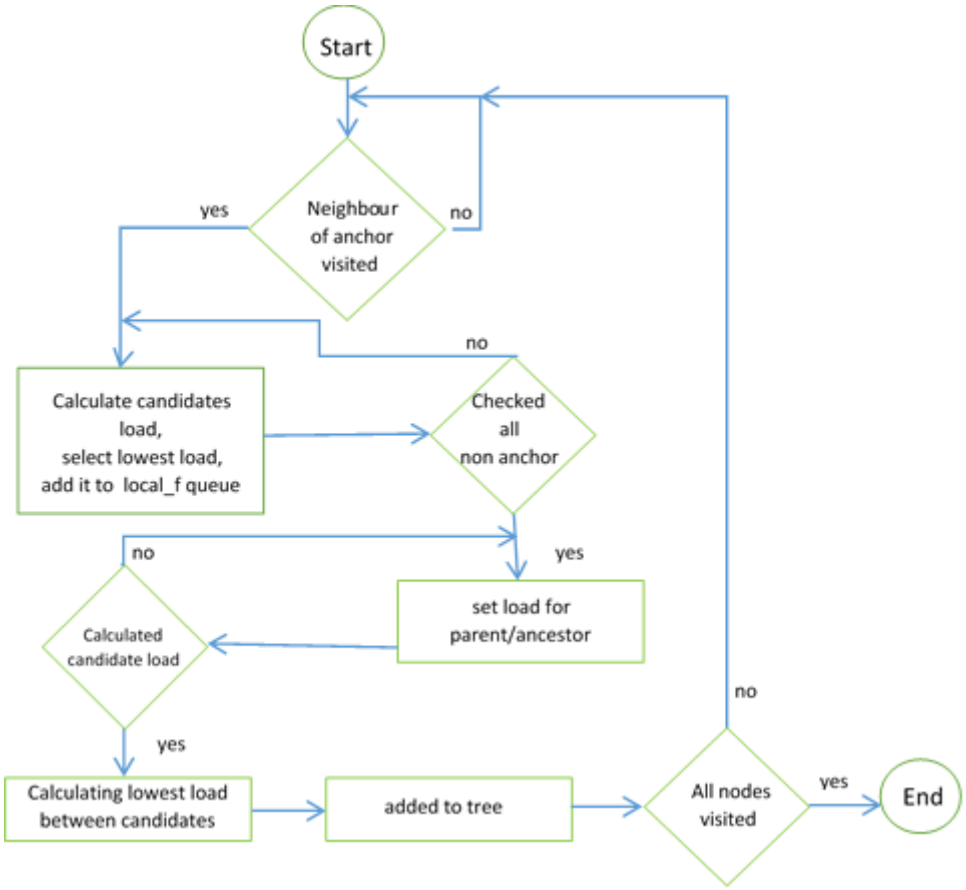

Figure 4. Finding Non-Anchors

Three limits — threshold, warning, and death — are defined for network nodes. In each round of energy simulation, when each node needs to send its data to the next node, the remaining energy is specified in a table. If the remaining energy in a node reaches the threshold (twice the minimum energy stored for each node), we enter the local search step, where that node is labelled and the children of that node should be separated from their parent and the parent selection process should be re-established for them. This reduces the speed of energy loss of the labelled node, and this helps to increase the network lifetime throughout the network. The reason for choosing the threshold as double the minimum value is that, if the remaining energy of the node reaches twice its minimum stored energy, it will have the opportunity to increase its lifetime by entering a local replacement phase. This means that, with two sink moves, the node will not be able to send/receive data in the network and will be removed from the data transfer in the network. But if we can make this node consume less energy in each sink move, it makes its lifetime increase. The warning threshold means that, if the remaining energy in the node is three times the minimum energy stored for the node, we will enter the phase of finding new neighbours. If the remaining energy in the node is less than the minimum amount

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of energy stored for the node, the condition for the death of the node is fulfilled and that node will be removed from the data transfer in the network.

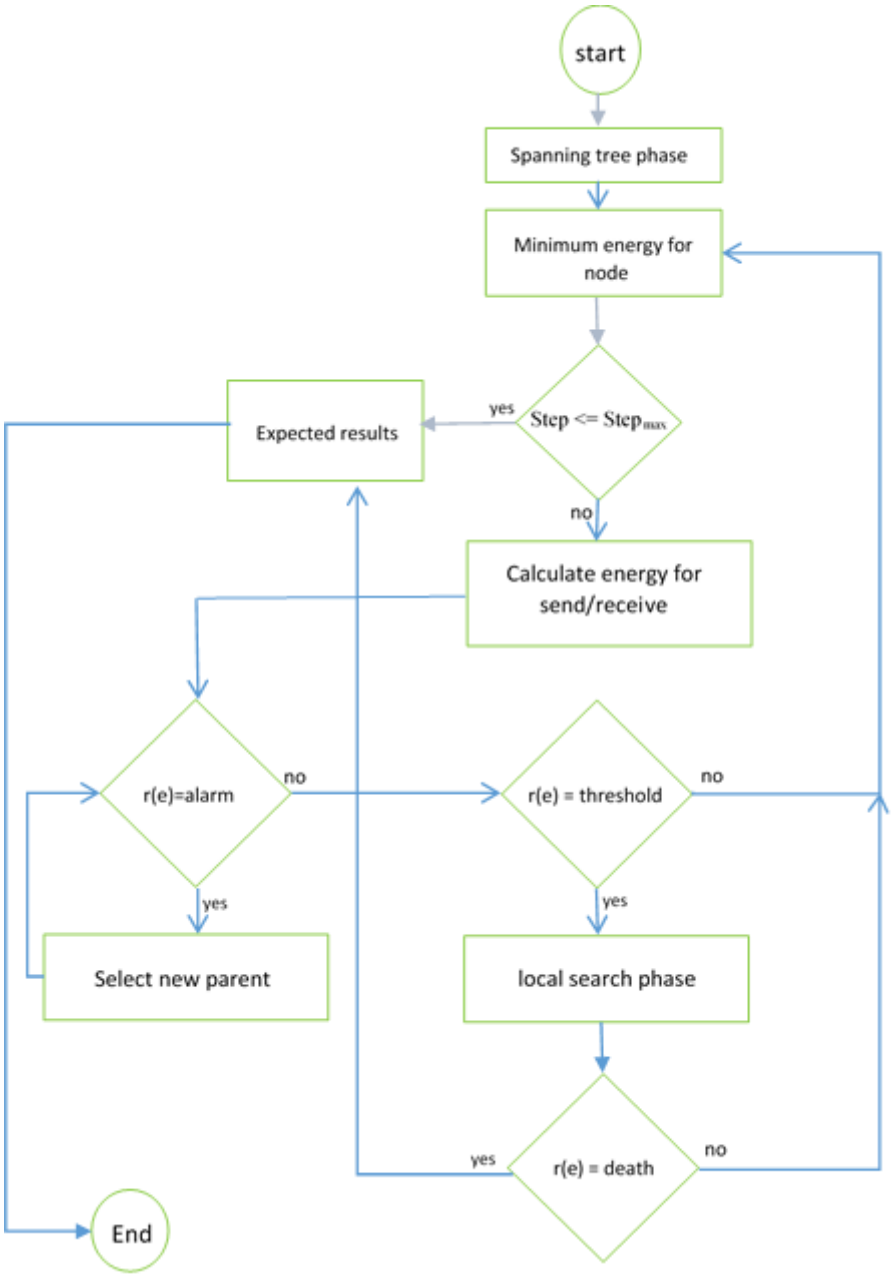

Figure 5. Proposed Method

The reduction of the number of child nodes of a node means shifting the load to subtrees. In the local search phase, the child nodes are separated from that node and a new parent is chosen for them. Thus, the energy consumption of the desired node is reduced. Meanwhile, if a node x that has reached the threshold has only one child and there is no other child in the neighbourhood of that node, the child node is separated from node x and is detached from the network during the local search phase. To prevent being isolated from the network, the warning threshold is used. If a node is placed in such a case, another node is introduced as the parent node of that node.

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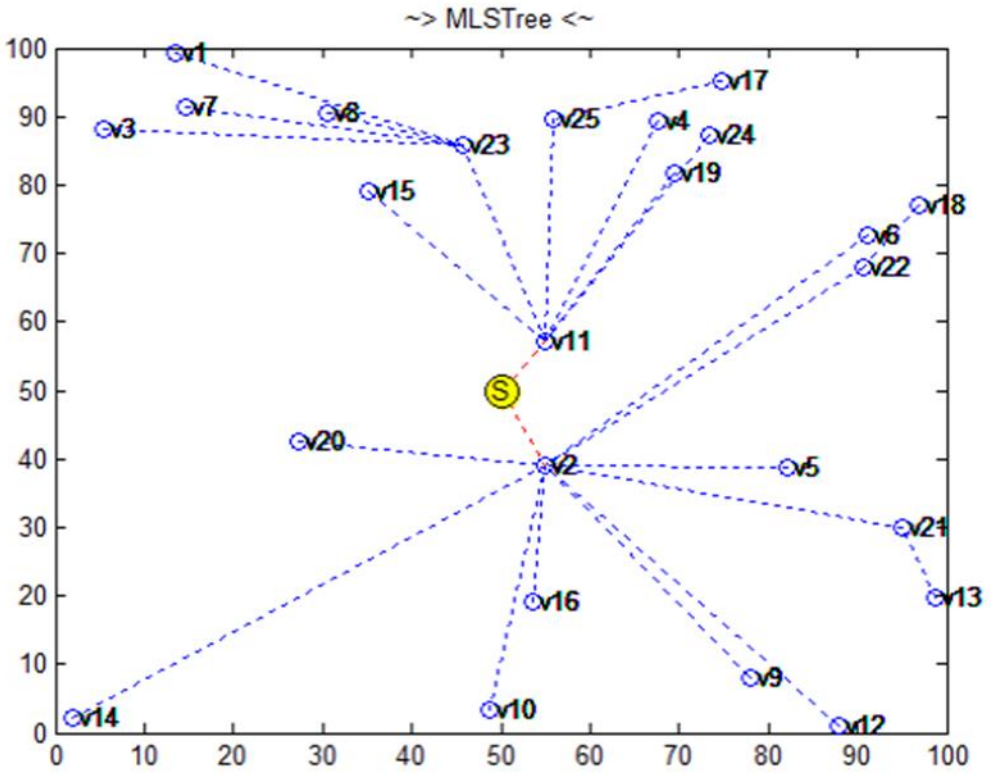

Figure 6. Completed network with the proposed method. S-node is a hypothetical central node in the simulation, which is the starting point for building a spanning tree from this hypothetical node. The nodes connected to the S node by the red dotted lines are the anchor nodes in the network (meaning the nodes closest to the sink node when the sink is moving). Nodes connected to anchor nodes or other nodes with a blue dotted line are normal nodes, whose job is to listen to their surroundings and send the information heard to the next nodes, or as a sink to receive data from previous nodes. Finally, leaf nodes are normal nodes that only listen to their surroundings and send the received data to their next nodes.

As stated earlier, the warning threshold and the threshold are used if, after making a spanning route, the traffic of sending packets on a node increases; then, the load on that node can be divided over the rest of the nodes in the tree. By doing this work, it is possible to claim that the network lifetime has increased over the situation before. To obtain the remaining energy, simulated annealing (Kirkpatrick, Gelatt & Vecchi, 1983) and variable neighbourhood search (Yetgin, Cheung, El-Hajjar & Hanzo, 2017) were used. We are looking for a tree that has least construction cost. The purpose of the cost is to select the node with the minimum load from the tree nodes with the highest load. Figure 6 indicates an example of a completed network.

First, an initial solution is needed to consider a neighbourhood relationship among the nodes. We take the cost of building a tree as the initial solution and enter the simulated annealing phase. For all the sets of responses, changes are made to the generated answers by using the neighbourhood function. Afterward, the cost of the obtained response is compared with the cost of the best answer so far. If the answer is better (minimum) than the best answer so far, the answer is replaced by the better answer. Otherwise, by creating a random number and a

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Boltzmann probability function, we are looking to accept the worse answer as well. If this is not true, the best answer will not change (see Algorithm 1).

```
Initialization
Number of Population;
Number of Move toward Neighbours;
Initial temperature and find temperature and T = To and α is reduction rate;
Initialize best_sol.cost = Inf;
Pop = Generate Population (with random solution);
If Pop.cost <= best_sol.cost then
best_sol = Pop;
Repeat until stopping condition is met (T <= T_F)
create and evaluate new_solution for Number of population and moving;
new_pop = create Neighbour for every member of population;
for I <- 1 to number of pop do
                    if new_pop.cost <= pop.cost
                              Pop = new_pop;
                    elseif rand < TempFunc(new_pop.cost,Pop.cost,T)
                              best_sol = Pop;
          store best_sol;
T = α × T;
```

Figure 7. Algorithm 1. The pseudo code of the proposed method with SA

```
Initialization
    select the set of neighbourhood structures
    NK
    Find an initial solution x
Repeat until stopping condition is met
   Set K = 1;
   Repeat until K = Kmax
        1 – Do_Shaking : Generate a random point X` in NK(X);
        2 – Local_search : X`` is optimum obtained;
        3 – Move / not Move:
          -if X`` is better than X, then x = X`` and k = 1;
          -else K = K + 1;
```

Figure 8. Algorithm 2. Pseudo code of VNS (Yetgin, Cheung, El-Hajjar & Hanzo, 2017)

The next algorithm is Variable Neighbourhood Search (Yetgin, Cheung, El-Hajjar & Hanzo, 2017) (Algorithm 2). The algorithm uses two parameters: “vibration” and “local search”. Vibration generates diversity and local search looks for the most appropriate answer. The vibration section creates a fundamental change in the initial response. Since it takes a lot of time to search the entire problem space, using vibration produces diversity in the answer to almost make sure that every state of the answer is checked (see Figure 9).

In the local search phase, if an answer is found better than the current solution, it will replace the current solution. Otherwise, it goes to other areas to compare their answers to the current solution. This work is conducted to the end of the specified time in local search. Finally, the output of this stage is compared with the best answer that already existed. If the solution is better than the current solution, then the new solution replaces the current solution. Otherwise, the vibration is performed on the last answer obtained from the previous step to check again the answers of that range.

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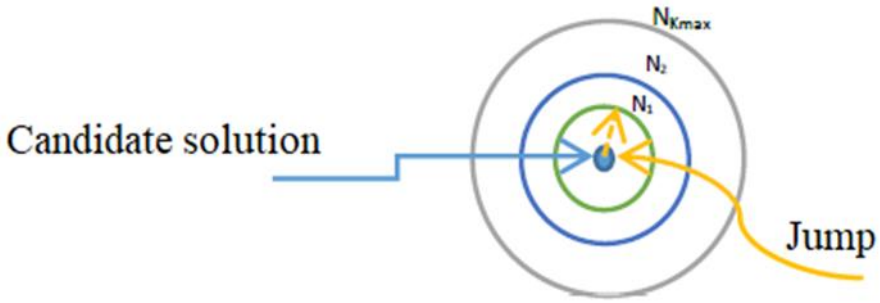

Figure 9. Variable Neighbourhood Search (Yetgin, Cheung, El-Hajjar & Hanzo, 2017)

Simulation and Results

In this section, in order to simulate the proposed method and compare it with Zhao, Guo, Wang & Wang (2015), the ns2 simulation with mannasim is used. Ns2 is an event-based, open-source software package. In this simulation, it is assumed that the simulation environment is 1000 metres by 1000 metres and consists of 100, 130, 160 and 190 wireless sensor nodes along with a mobile sink. For routing, the AODV protocol has been used and the radio antenna is omnidirectional. All parameters are presented in Table 1.

Table 1: Parameters

Parameter	Value
The primary energy of each node	0.2 J
Area of simulation	1000 mx1000 m
Number of sinks	1
MAC type	Mac/802.11
Clustering algorithm	LEACH

To achieve the simulation results, the number of rounds has been executed 25 times, with each execution having 1200 runs. Next, the mean of these 25 executions was obtained and the mean values are recorded in the results.

Figure 10 shows the mean end-to-end delay among nodes, in milliseconds. After 25 executions for 100 nodes in the proposed method, the average delay is 0.5543 ms, while in the method of Zhao, Guo, Wang & Wang (2015) it is 0.67424 ms. When the number of sensor nodes is 130, the average delay in the proposed method is 0.58725 ms; however. in the method of Zhao, Guo, Wang & Wang (2015), it is 0.719874 ms. In addition, when the number of sensor nodes is 160, the average delay is 0.676539 ms, compared to 0.794338 ms in the method of Zhao, Guo, Wang & Wang (2015). Finally, when the number of sensor nodes is 190, the average delay

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in the proposed method is 0.8725 ms, as opposed to 0.898538 ms in Zhao, Guo, Wang & Wang (2015).

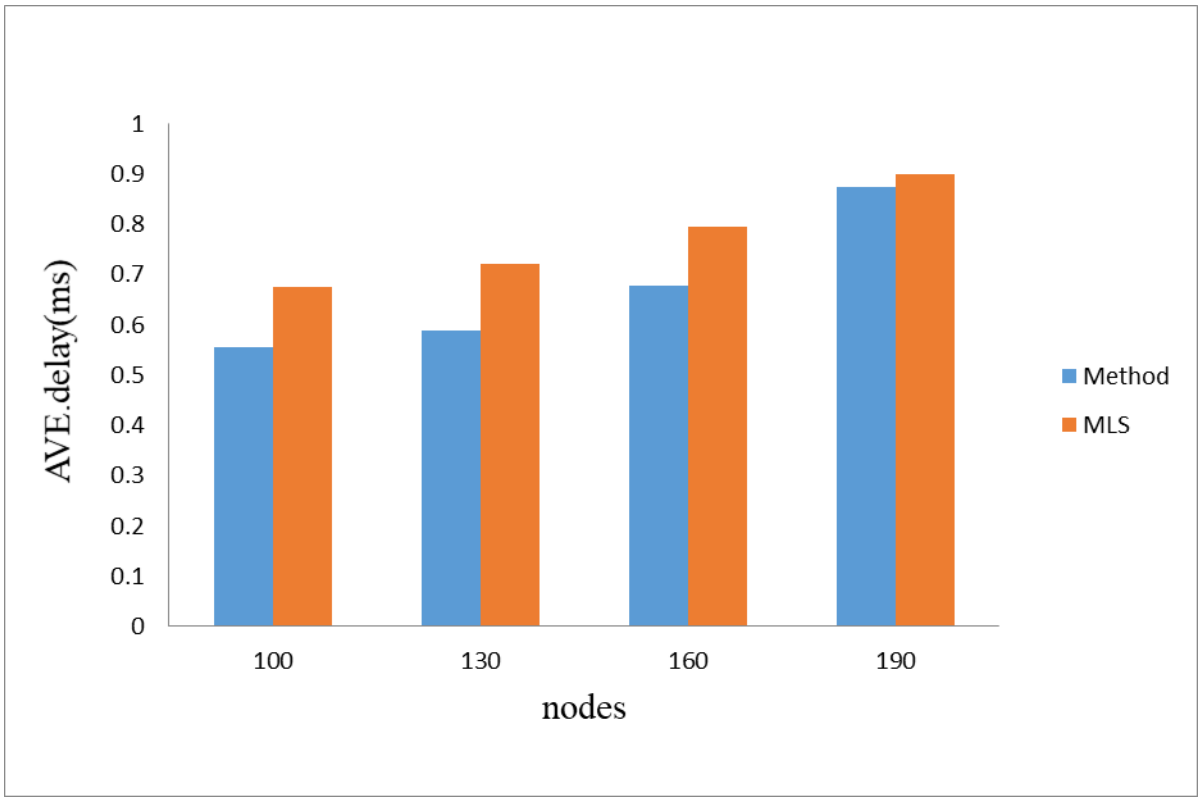

Figure 10. The comparison of the average end-to-end delay in the sensor network between the proposed method and Zhao, Guo, Wang & Wang (2015)

In Figure 11, the energy consumed in the sensor nodes is exhibited. For 100 nodes, the average energy consumption after 25 runs in the proposed method is 17.5 J, whereas in Zhao, Guo, Wang & Wang (2015) it is 18.8 J. For 130 sensor nodes, the average energy consumption in the proposed method is 21.3 J, compared to 24.2 J in Zhao, Guo, Wang & Wang (2015). For 160 and 190 sensor nodes, the proposed method consumes less energy than the method in Zhao, Guo, Wang & Wang (2015): 28.39 J and 32.14 J, respectively, compared to 31 J and 35.83 J.

Figure 12 compares the sensors' lifetimes based on the number of dead nodes between our method and the method proposed in Zhao, Guo, Wang & Wang (2015). A sensor node dies because its battery has limited energy that is consumed over the time of the sensor node's activity (depending on the type of node activity). Thus, its energy decreases as its battery is consumed and not recharged. This causes the sensor node to lose its energy after a while and it can no longer continue to operate, including sensing the surroundings and sending or receiving data. When the number of nodes is 100, the numbers of dead nodes in our method and in Zhao, Guo, Wang & Wang (2015) are 13 and 16, respectively. Further, when the number of nodes is 130, the number of dead nodes in our method is 19, slightly fewer than the 23 dead nodes in Zhao, Guo, Wang & Wang (2015). Similarly, for 160 and 190 sensor nodes, the

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numbers of dead nodes in our method are 23 and 31 in turn, as opposed to 32 and 40 dead nodes, respectively, in Zhao, Guo, Wang & Wang (2015).

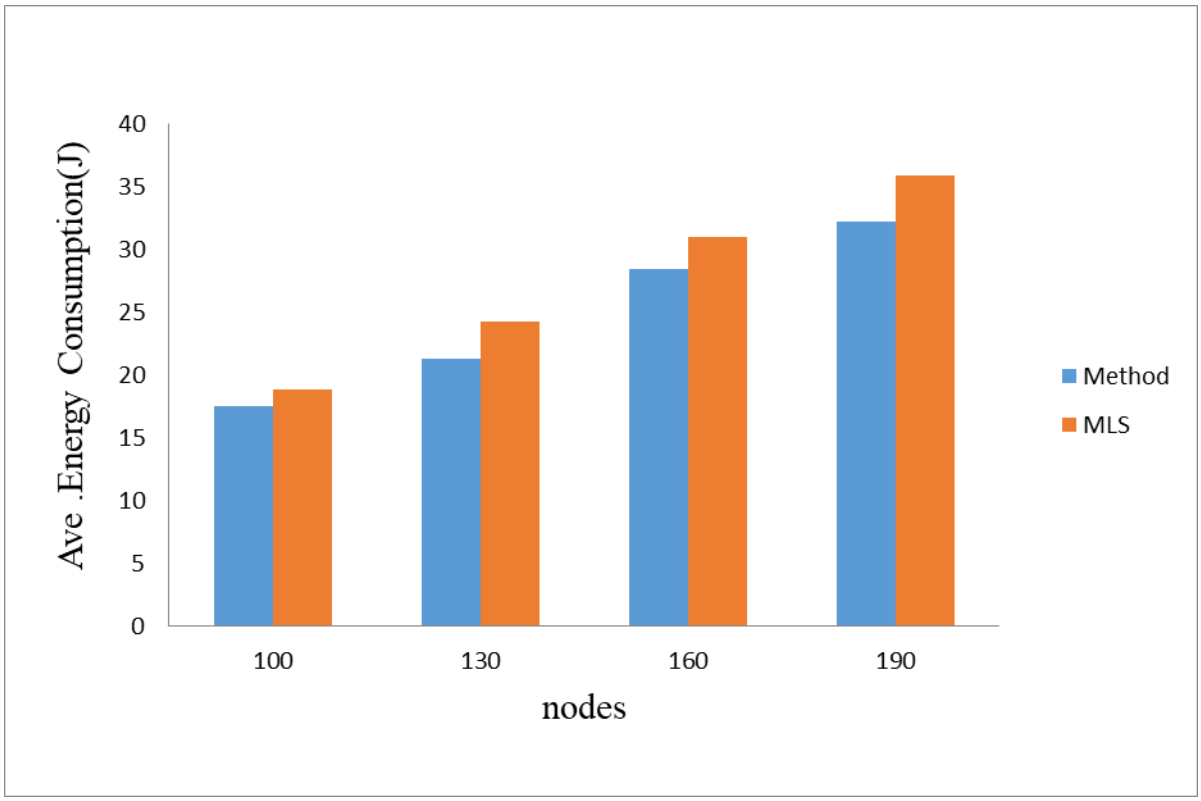

Figure 11. The comparison of the average energy consumed in the sensor network between the proposed method and Zhao, Guo, Wang & Wang (2015)

Figure 13 indicates the comparison of average packet delivery rates among network nodes for the proposed method and Zhao, Guo, Wang & Wang (2015). When the number of nodes is 100, the average packet delivery rate in the proposed method is 85%, compared to 79% in Zhao, Guo, Wang & Wang (2015). When the number of nodes is 130, the average packet delivery rate in the proposed method is 81.84%, as opposed to 78.93% in Zhao, Guo, Wang & Wang (2015). For 160 and 190 sensor nodes, the average packet delivery rates in the proposed method are 84% and 85% in turn, while in Zhao, Guo, Wang & Wang (2015) they are 77% and 79%, respectively.

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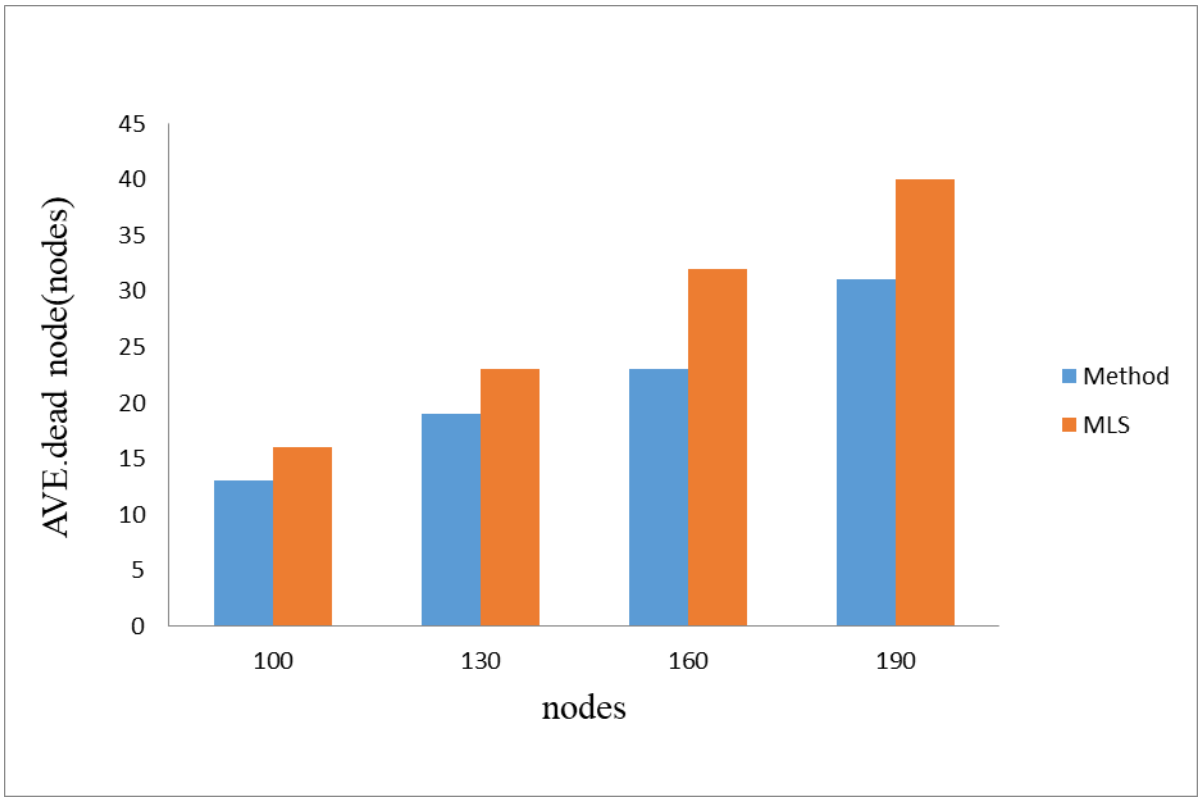

Figure 12. The comparison of the average sensor lifetime in the sensor network between the proposed method and Zhao, Guo, Wang & Wang (2015)

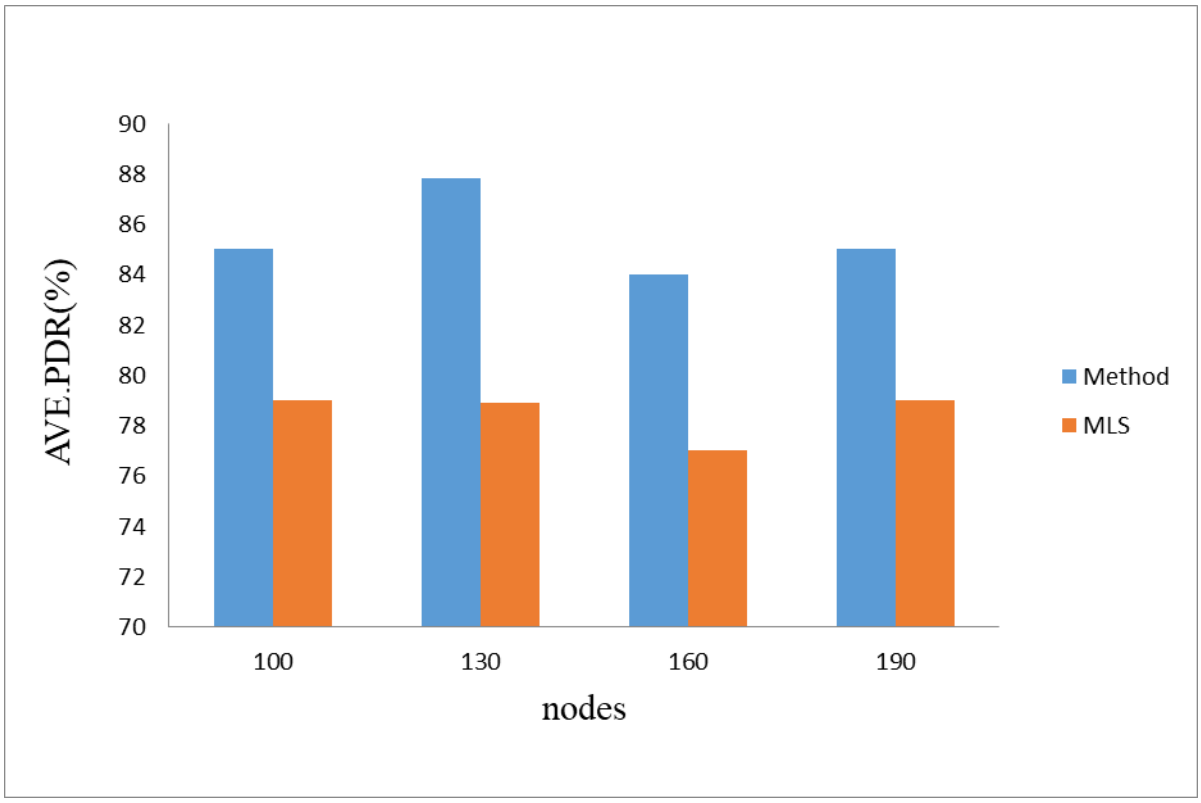

Figure 13. Comparison of average packet delivery rates among network nodes between the proposed method and Zhao, Guo, Wang & Wang (2015)

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Conclusion and Future Work

Considering the many applications of wireless sensor networks and the great passion for using them, they still face challenges, including energy consumption. In this study, we developed load balancing by using proper connectivity control between the sensor nodes and the definition of three limits, including thresholds, warnings, and deaths for sensor nodes. Moreover, with the help of two metaheuristic algorithms, SA and VNS, the lowest cost spanning trees for the sensor nodes were found. The results of the simulation show that the network lifetime in the proposed method has been improved and enhanced compared to Zhao, Guo, Wang & Wang (2015).

As future work, in order to evaluate the sensors' lifetimes before forming the connectivity tree, the MPLM method (Hao *et al.*, 2018) can be used. In the proposed method, we can actively use the durability or persistence of sensor nodes in the network. As a result, the connectivity is established among sensor nodes through including the best mode and network status; this improves the network lifetime. The second suggestion is using an information packet that is exchanged among all sensor nodes and includes their current status (active/deactivated). This packet has the status of all sensor nodes and this information can be used for better routing of the mobile sink.

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