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A 5G RURAL, REMOTE, AND DIFFICULT AREAS HOPE: A REVIEW

Harry Candra Sihombing[1]*
Department of Electrical Engineering, Universitas Mercu Buana, Indonesia

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ABSTRACT

The 5G cellular networks are "urban" areas technology in nature, extensively deployed in high density to provide high data rates, with low delays for high mobility of users. On the contrary, one-third of people living in rural zones experience a lack of mobile broadband connectivity. These are recognized as the main barriers impairing the Sustainable Developing Goals (SDGs) defined by the United Nations. Those low revenues areas that are not covered will be unlikely to be covered soon as the network operators are not keen to invest in such zones. 5G will meet stringent requirements in urban zones, while rural areas in developing countries will experience virtually non-existent mobile broadband underdevelopment. The use of traditional backhaul technology is no longer the right solution and this is still the biggest problem in remote villages that are rarely inhabited by low-income communities for operators because it does not guarantee a good ROI (Return on Investment).

Correspondence:
Harry Candra Sihombing,
Department of Electrical Engineering,
Universitas Mercu Buana, Indonesia,
Email: chandra.harrys@gmail.com

INTRODUCTION

The Arpanet first experiment took place on 29th October 1969, with a simple login message exchanged in a network as the Internet has become an open, safe, trustworthy and accessible engine of social and economic growth. However, the lack of connectivity and/or coverage is still experienced by many people, especially rural and low-income areas, areas with low density, and cities/cities with low Gross Domestic Product (GDP). There are several possible types of connection to the Internet for these areas via WiFi, radio access, fixed access, and satellite connection [1].

The "converged solution" of the 5G concept is delivered high bandwidth, high-performance, and extremely low delay to users are possible by an extremely rich and complex architecture, including heterogeneous networks of macro and small cells, front haul, and backhaul transport networks, small computing nodes deployed close to the users, and large data center.

In [2] explained, the deployment of telecommunication network infrastructure for rural, remote, and difficult to access (RRD) areas with sparsely populated areas requires high investment. While 5G broadband radio access is characterized by short cell coverage, with several hundred residents per square kilometer to benefit.

Figure 1. The evolution of mobile technology [2]

Furthermore, the 5G wireless system's future requirements many other machine type IT-systems lead to a breakthrough in designing extremely green flexible, and low-cost technologies for which will be able to reach in real-time the performance extremums, trade-off optimums, and fundamental limits.

Also in [3] mentioned, the importance of prospective 5G communications networks profound is the energy efficiency of broadband mobile services, especially in dispersed populated rural areas at a reasonable cost. The challenges of high data speed wireless connectivity are increasingly real and severe when dealing with rural and remote areas with very low population densities. The 5G communications networks concept of ”broadband access everywhere” and high-quality connectivity at a low cost is needed for the solutions.

In [4] describes, the evolutionary improvements of forthcoming 5G communications technologies differ by the centralized hierarchical low-meshed architecture and short-range cells. Radio access nodes (RAN) connections such as centralized networks with well-developed fiber-optic infrastructures will be profitable in highly populated areas. These evolutionary of the 5G communications systems differ also by not enough dynamic and stability of the methods of bandwidth resources allocation and QoS control, and insufficient tolerance to the long-delay wireless medium.

In [5], cities are a suitable area for high data rates on a 5G mobile network, where the user population is high, coupled with very low delays with very high user mobility. Meanwhile, there are still many people in the world who experience a lack of mobile broadband connectivity who live in areas that are difficult to reach by technology.

As [6] also mentioned, Soon, the global 5G ubiquitous network strategy that aims at deploying heterogeneous technologies for internet access, involves also rural RF deployment. 5G’s will certainly meet stringent requirements in urban zones, but the outermost areas still have minimal mobile broadband coverage and are uneven and almost non-existent, especially in poor countries. To cope with this issue, major insights dug into the use of TV spectrum gaps, which offers a lot of advantages in enhancing the global system capabilities. This paper explores the capabilities of TVWS in rural, poorest, underserved areas through a new approach to optimize internet access there.

One of the biggest challenges in wireless communication for the next generation networks is to address the maximum users possible that are densely distributed over a unit area. We plan for the arrival of this tremendous number of smart devices that are running various bandwidth-consuming applications. To address this issue, which is mostly found in dense urban areas, multiple access techniques and coexistence management between heterogeneous technologies have been investigated for unlicensed bands [1]. In our case, the problem faced is the very low coverage of some areas in African countries. The main problem for outermost areas, with small populations and low incomes, is that they still take advantage of the classic access to traditional backhaul technology which is an imprecise solution for mobile network providers because even this does not guarantee the desired return on investment. One of the solutions that have been approved is the use of Cognitive radio features in a licensed band [2]. Indeed, it appears that these leased bands, assigned to incumbent users, even saturated because of the various applications and standards operating within it, can open up new opportunities [7].

In [8] taking an example in New Zealand, set internet broadband access to reach 90% with a speed of half of 100 MB by 2025 and the remaining 10% can access broadband with a speed of not less than 10 Mbps. It aims to address the challenges of connection complexity in rural areas including collaboration between various network access technologies to increase geographic reach, different stakeholders to optimize social and economic outreach, through collaboration between national and international communities from various disciplines to maximize affordability.

The United Nations has launched the Sustainable Development Goals (SDGs) initiative, to mobilize global action to end poverty, protect the planet, and deliver prosperity for all humankind. The people living in rural and low-income areas generally are well above 80% in developed countries, face access problems due to the substandard or no connectivity. Low-income and rural areas could be left with substandard or no telecommunication infrastructure if there are no Government subsidies on offer. Network development by operators usually prefers areas with high population density to get a guarantee of adequate Return on Investment (RoI) [8].

In [9] give a fact, About two billion people cannot enjoy the coverage of the telecommunication wireless cellular network, mostly living in rural areas and low-income areas, as well as outermost areas, coupled with the scarcity of the electricity network. The International Telecommunication Union (ITU) reports that only nearly 70% of the world's population has enjoyed third-generation (3G) networks. The 5G vision of a “converged solution” has several advantages for the spreading of Internet connectivity with a high level of flexibility. Network services and resources can be used to provide high bandwidth and very low delay to users where when they are needed by substituting Hardware

(HW) commodities with Software (SW) solutions that implement network functionality can potentially lower costs when installing and maintenance of the device.

RELATED WORKS

Then [10], describe a Bring Your Own Device (BYOD) as a policy that allows workers to carry their mobile devices with them to perform work tasks, connecting to the network and corporate resources. As a result, carries a lot of advantages such as increase the company's economy, making the company more competitive by reducing its operating costs. Business policies of this human activity should follow national policy guidelines to regulate the activity, to guide its use safely and properly, providing privacy in all social and economic activities due to security risks in the internal information system.

A policy needs to be easy to access; easy to understand and allow feedback, this policy should need to follow these aspects [10]:

- A secure device with passwords and two-factor authentication methods.
- Password must consist of more than 16 characters, alternating between numbers and letters without any meaning
- A trained process in application usage and download/installation best practices.
- As it happened, need to report stolen/lost devices to minimize security risk.

Through a systematic review, [11] identify and analyze recommender systems developed in the health area, on Android-based mobile applications. As it found that Collaborative Filtering and Content-based Filtering as recommendation systems intended to suggest items as input. The system transforms and directs them to the appropriate targets to satisfy in some respect the needs of a user using the mobile devices and widely available data connections, via private/public Wi-Fi or 3G, 4G, and other networks.

Collaborative filtering uses the similarity of user profiles, that seek to predict the evaluation of items for unrated users. This technique involves three phases:

- The first phase is using Cosine metrics, Pearson Coefficient metrics to calculate the similarity of the user profile with the existing user profiles for a recommendation.
- The second phase, obtaining a list of user's profiles with greater similarity.
- The third, the similarity calculated in the first stage is used as the weighted sum of the rating of an item to get its predictive value.

The Matrix Factorization is used in the calculation of this similarity [11].

In [12], mention the usability and contributions of classical and present approaches in critical systems with virtual reality in the area from the cognitive engineering approach. Then compile the type of evaluation carried out (heuristic, cognitive, ergonomic) to correlate it with human-computer interface analysis, which can contribute to the stages of user analysis, proposals, and prototype development as outlining system analysis.

Then [12] describe a Critical Systems investigation where the determination of accuracy and usability for multimodal interactions and the use of non-conventional devices to understand the challenge in cognitive engineering will contribute to the development of critical three-dimensional systems, provide a combined understanding of cognitive engineering, critical systems, and virtual reality in the context involved and the usability.

The selected journal done by [11] is quite simple and short. Besides, the journal [12] is written in Portuguese so it will not be used as a reference because of the limitations of the author to understand the language. Although researchers try to translate the introduction part using Google Translate to understand more, limited translation results cause doubts and become obstacles. But it is enough to open a new understanding.

RESEARCH METHOD

A systematic review is a good tool in doing research, from several searches in a database then researchers selected 3 journals as a basic framework in completing a systematic review as follows:

- National Cyber-Security Policies oriented to BYOD (Bring Your Own Device): Systematic Review [10].
- Recommender Systems in Mobile Apps for Health a Systematic Review [11].
- Systematic Review on Cognitive Engineering Applied to Critical Systems for Proposition of Evaluation Heuristics for Virtual Reality Systems [12].

The phrase related to a systematic review in this journal was done as shown in table 1.

Table 1. Evaluation phases of the studies

Phase	Sections Evaluated
First	Title of the study
Second	Abstract and Conclusion and or Further works
Third	Study in full

Questions need Answer

In a systematic review, there are one most important steps to be answered by doing specific research [10]. The questions of this research were:

Q1 - What are the 5G technology areas covered in terms of?
Q2 - What are the techniques used to generate quality recommendations?
Q3 - What tech companies and government can do in these studies?

Parameter and Search Studies

The Systematic Review objective is to identify and analyze the 5G systems available in Rural Areas without double quotes [13], each keyword separated by white space. This search phase did by three phases of searching. The first is by providing the ”5G” keyword into the search field, then in the second phase by adding Rural as it was ”5G Rural” and the third phase add Areas as it becomes ”5G rural Areas”. This was performed in, IEEEXplore (http://ieeexplore.ieee.org) database, on 27 December 2017 without a year's limit of publication.

This study creates a search strategy based on eligibility criteria considered the research questions. Thus, three keywords were selected for the search: 5G and Rural Areas. Then bring the research conducted to identify the desired meaning for the selected keywords in the databases and validate them. As shown in Figure 2 the defined search strategy validation.

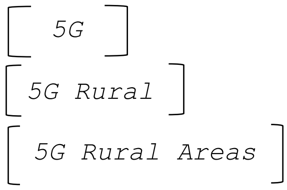

Figure 2. The search strategy of primary studies

Selection Studies

There is a total of 2000 publications search results using the ”5G” keyword, and 13 publications search results using the”5G Rural” keyword. Then by using the Conference filter, the search results have 10 publications and 1 publication search result when Journals & Magazines filter were applied. In term search using ”5G Rural Areas” keyword resulting 9 publications. Then by using the Conference filter, the search results have 8 publications and 1 publication search result when Journals & Magazines filter were applied. The selection of journal results is based on keyword searching it as shown in figure 3.

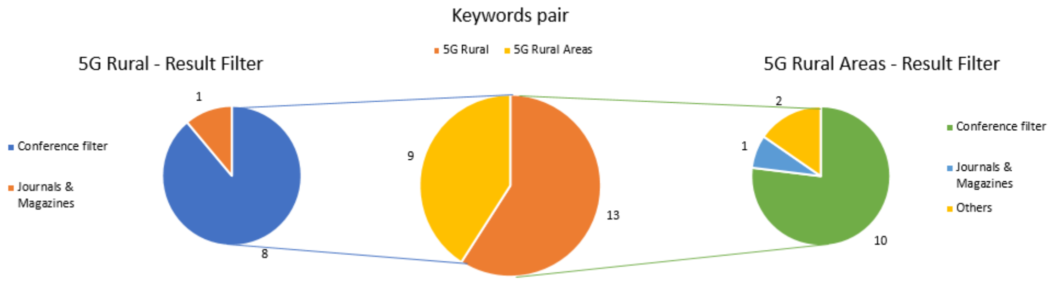

Figure 3. The selection results of the keywords search

The stages of the evaluation study, selecting and searching for keywords to obtain sufficient information was carried out on the journal publications as shown in figures 3 and 4.

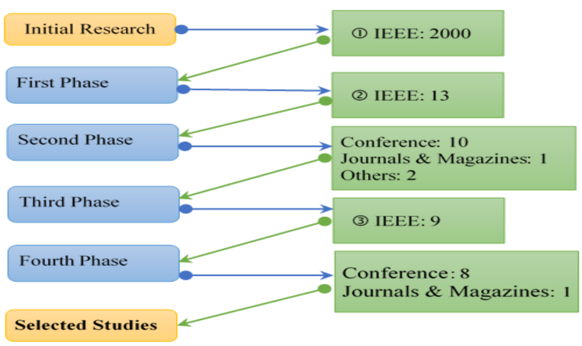

Figure 4. The selection phase of 3 keywords

RESULTS AND DISCUSSION

The selected primary journal is listed in Table 2. Regarding the areas of applicability each discussing the readiness and feasibility and utilization of 5G in the rural area [1], [9], two journals discussed The Cost-Effectiveness And Optimal Pricing Strategy related to the utilization of 5G communication network in the rural area [2], [5], one journal discusses Performance Modeling and Optimization [4], [14], two journals discussing Enhancing Connectivity and Connecting the Unconnected [6], [8] and one discussing Energy-Efficient, Green, Flexible, and Profitable [3], [7].

The selected study is then grouped into the main sub-topics as can be seen in Table 2. Grouping is done based on the selection of the main keywords contained in the title of the selected journal. The discussion of selected journals is summarized as follows.

Readiness and Possibility

The 5G communication network has a high level of flexibility, high bandwidth, and extremely low delay, possible to deploy services and network resources where and when they are needed to deliver and spreading the Internet connectivity by the extensive deployment of small cells, suggest that it will be used primarily in very densely populated urban zones, with a sufficient number of customers to balance operating costs on a profitable business. Meanwhile, in low-income rural zones with very low population density, it is not possible to deploy 5G networks. The great barriers are the lack of revenues per square mile even an increase in the competition in the spectrum assignment [1].

The exploitation of massive Multiple Input Multiple Output (MIMO) beamforming reducing the number of cells deployed per area size can reduce the power consumption of the network area by half compared to standard cellular networks while ensuring that the cell edge user throughput power approaches 10 Mbps [1].

Table 2. Selected Primary Studies

Study	Document Title	Authors	Year	Document Identifier	Selected keywords	Results and discussion topic selected		Study
[1]	5G in rural and low-income areas: Are we ready?	L. Chiaraviglio; N. Blefari-Melazzi; W. Liu; J. A. Gutierrez; J. Van De Beek; R. Birke; L. Chen; F. Idzikowski; D. Kilper; J. P. Monti; J. Wu	2016	IEEE Conferences	Rural and low-income areas	A.	*Readiness and Feasibility*	[1][9]
[2]	Cost-effective ubiquitous IoT/M2M/H2H 5G communications for rural and remote areas	A. Markhasin; V. Belenky; V. Drozdova; A. Loshkarev; I. Svinarev	2016	IEEE Conferences	Cost-effective	B.	*Cost-Effective and Optimal Pricing Strategy*	[2][5]
[3]	Energy-efficient 5G deployment in rural areas	A. Karlsson; O. Al-Saadeh; A. Gusarov; R. V. R. Challa; S. Tombaz; K. W. Sung	2016	IEEE Conferences	Energy-efficient	C.	*Performance Modeling and Optimization*	[4]
[4]	Leverage multifunctional MAC performance modeling and optimization with guaranteed QoS for profitable 5G IoT / M2M systems in rural and outermost areas	A. Loshkarev; A. Markhasin	2016	IEEE Conferences	Performance modeling and optimization	D.	*Enhancing Connectivity and Connecting the Unconnected*	[6][8]
[5]	Optimal pricing strategy for 5G in rural areas with unmanned aerial vehicles and large cells	L. Chiaraviglio; W. Liu; J. A. Gutierrez; N. Blefari-Melazzi	2017	IEEE Conferences	Optimal pricing strategy	E.	*Energy-Efficient, Green, Flexible, and Profitable*	[3][7]

[6]	Toward enhancing connectivity through TVWS in an outdoor rural isolated environment	L. M. Amine; E. B. Adil; P. H. Aawatif	2017	IEEE Conferences	Enhancing connectivity			
[7]	Fundamentals of the extremely green, flexible, and profitable 5G M2M ubiquitous communications for remote e-healthcare and other social e-Application	A. Markhasin	2017	IEEE Conferences	Green, flexible, and profitable			
[8]	Connecting the unconnected 10% of New Zealanders by 2025: Is a MahiTahi approach possible?	M. Villapol; W. Liu; J. A. Gutierrez; L. Chiaraviglio; A. Sathiaseelan; J. Wu; A. Bagula; J. Qadir; J. Song; W. Zhang; M. A. Gregory; J. Wu	2017	IEEE Conferences	Connecting the unconnected			
[9]	Bringing 5G into Rural and Low-Income Areas: Is It Feasible?	L. Chiaraviglio; N. Blefari-Melazzi; W. Liu; J. A. Gutierrez; J. van de Beek; R. Birke; L. Chen; F. Idzikowski; D. Kilper; P. Monti; A. Bagula; J. Wu	2017	IEEE Journals & Magazines	Feasibility			

The problem, however, the cost of solar-powered cells provides far less power than exploit power derived from diesel generators. The cost-reducing was also made possible by applied different power over time based on the traffic variability and virtual network elements, for example, utilizing Cloud Radio Access Networks (C-RAN), Network Function Virtualization as functionality are another way to reduce the cost and improve the resource efficiency in a transport network [1].

The adoption of 5G in rural areas and outermost areas with low income is even more important to ensure basic coverage of high bandwidth service availability with certain features of the specified scenario. The minimum amount of bandwidth allotted to the user must remain guaranteed. Thus, the related business models in these zones cannot be based solely on Return On Investment (ROI). The internet must be considered as a primary essential need that must be provided by the government. Affordability remains a socio-economic challenge in developing mobile networks as citizens wish to use them effectively to improve their living conditions [1].

Governments and policy-makers need to understand the technical aspects of networking and their services, as well as the interplay between technological and public policy domains. Finally, the impact of networking on the environment is also critical. Network development for energy efficiency, smart systems, and services will enable increased productivity. However, the network system has also become a source of emitting greenhouse gases (GHG) which continues to increase as the network expands. So that services and networks must be managed flexibly when deploying services across various components across the network, while still meeting the requirements for delivering 5G architectural connectivity [1].

– Converged Solution

The government-based managed must design and deploy the services in different components network entities to justified rural and low-income.

– Network Reusability

The utilization of virtualization of network components on various components of the same network on different physical devices can be done by utilizing software that is managed by centralized control. Although currently the utilization and performance of virtualized network elements are still lower than that of fully hardware-based components.

– Hardware Exploitation

Traditional network functions consisting of proprietary hardware as well as hardware code will be less flexible, and difficult to manage. It is then possible to deploy the same general purpose hardware for most of the network components cheaper and also reduces operating costs.

– Solar-Powered Devices

It is almost certain that there is no reliable energy available in rural and low-income zones to power networked physical devices. This is a clear sign of the need to exploit renewable energy through the use of solar panels with smart energy-efficient governance in controlling the amount of energy consumption demanded.

– Unmanned Aerial Vehicles and Advanced Radio Techniques

Physical radioelements can be mounted on top of Unmanned Aerial Vehicles or above balloons in the atmosphere to follow users on rural networks for increased connectivity. Where the spread of a large-scale radio element antenna array over an ultra-large cell size (over 50 km) [9] can be achieved by amplifying the beamforming to reduce propagation losses compared to classic Non-Line of Sight (NLOS) conditions.

Thus, the construction of 5G networks in rural areas and low-income zones can be built based on the following pillars: i) utilization of small Unmanned Aerial Vehicles (UAV), ii) exploitation of renewable energy sources, iii) reuse of network components and functions, iv) deployment of commodity hardware.

Cost-Effective and Optimal Economic Strategy

The unprecedented requirements and new features of the forthcoming Internet of Things (IoT), machine-to-machine (M2M), and many other machine type IT-systems lead to an extremely ecological green and cost-effective approach to the creation of the technologies for future 5G wireless systems without the increase of SINR [2].

The optimal economic framework that enables the utilization of 5G connectivity is through small cells mounted on top of Unmanned Aerial Vehicles (UAVs) and using large cells covering a wider area powered by solar panels and batteries installed at each cell location. However, what needs to be considered is the usage of the number of batteries and solar panel power for each site, the number of cells to support services for users, and the monthly subscription fees that will be charged to users. The opportunity to take advantage of software as a hardware replacement function by legacy networks can be exploited to limit the amount (and cost) of dedicated hardware installed on a 5G network. The utilization of MU-MIMO can trigger a substantial increase of the downlink data rate to reach the user terminal [5].

Performance Modeling and Optimization

In [4], propose a flexible QoS-guaranteed using multifunctional distributed dynamical medium access control (MAC) to the long-delay wireless medium for breakthrough improving an economical, spectral, and energy efficiency in the rural, remote, and difficult areas to bring broadband wireless access communications. The multifunctional technologies providing dynamic control and management "on the fly" of the broadband multiple access to the long-delay wireless medium for optimization, modeling, and design which meet the 5G for the sparsely populated rural, remote and difficult area challenges.

Enhancing Connectivity and Connecting the Unconnected

The network strategy of global 5G ubiquitous also aims to deploy heterogeneous radio frequency technologies for internet access in rural, remote and difficult areas. In urban zones, 5G will certainly be able to meet the stringent requirements that were asked. Unfortunately, especially in developing countries, rural areas are still suffering and waiting due to almost non-existent coverage of mobile broadband connectivity. The use of classic access using traditional backhaul technology is an inappropriate solution because there is no guarantee on ROI (Return on Investment) [6].

White Space TV can be a solution for providing internet access for rural areas with an attractive QoS and help build a strong backhaul and at a minimum cost. Another solution that has been approved is the use of Cognitive radio features in licensed band appears that these leased bands, assigned to incumbent users, even saturated because of the various applications and standards operating within it, can open up new opportunities [6].

5G aims to take advantage of technology and the advantages of spectrum sharing and reuse [8]. The utilization of wireless mesh/community networks is a bottom-up solution for sustainable development where users share their home broadband connection. Each node is capable of distributing data to other people in its environment for the common benefit of its users. Each participating node has reachability, throughput, and resistance to network expansion [8].

The use of aerial platforms can be a viable and efficient alternative to meeting universal service provision needs when providing terrestrial backhaul solutions for rural areas. This technology is expected to complement and support existing terrestrial and satellite wireless technologies [8].

Energy-Efficient, Green, Flexible, and Profitable

In the perspective of 5G wireless networks, energy efficiency is important, especially in rural areas, which is a formidable challenge where people are rarely populated with limited resources but still have to be able to deliver high data speed broadband cellular services at a reasonable cost [3], [15].

The 5G network is likely to be used in the higher spectrum at frequencies below 6 GHz, and the propagation of electromagnetic waves in the mmWave band in a 5G cellular system can take advantage of antenna array elements in a smaller size representation of multi-element antenna systems that support fully directional communication. with beamforming [3], [16].

CONCLUSION

The backwardness of rural areas, remote areas, and difficulty in having an internet network, especially in developing countries, is the concern and responsibility of all stakeholders. The entry of 5G technology will make remote areas even more left behind and forgotten. This 5G technology is mandated to be technically very oriented towards urban areas that have adequate user density.

However, rural, remote, and difficult areas are not simply abandoned and forgotten. The government is expected to be a solution to this problem by mediating between rural, remote, and difficult areas and telecommunications companies. The search for more efficient and environmentally friendly technologies is also encouraged to better reach rural, remote, and difficult areas.

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