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Choice of Wireless Technologies for Rural Connectivity - in the context of Developing countries

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Abstract

Optimisation of ICT brings measurable changes for development of a country. Initiation of telecenters, bridges the digital divide in rural areas, by empowering social interactions and networking among people. Internet connectivity is essential to enable services in telecenters. Among different wired and wireless connectivity options, selection of suitable technology for rural deployment is a must. In this paper, we limited our comparision to different wireless technologies like Wi-Fi, Wimax, CDMA450 and VSAT technologies, for deployment at a telecenter, with a motive to reach social goals such as e-education, telemedicine, e-livelihood, virtual agriculture etc. Comparision of wireless technologies is done using multicriterion 'decision making analysis tool' AHP (Analytical Hierarchy Process) to obtain a technology that better suits rural settings. Several attributes under the category of technical, social, environmental and economical aspects are taken for optimal comparision of wireless technologies.

Keywords: Telecenter, WiFi, Wimax, CDMA450, VSAT, Analytical Hierarchy Process, Jperf, Ping.

Introduction

Development of rural areas is one of the major concern in the area of Government's policies. The benefits that technology brings normally reach the few rich and elite people and most of the times rural masses have been underprivileged of these technology services. Experts' services in terms of education, livelihood, agriculture and health are unavailable to rural people, as they are mostly residing in urban environment. For these services to be utilized by rural people, internet connectivity plays a crucial role in delivering information.

Employing the ICT information and technology and its dissemination in rural areas by building telecenters, will address the needs and bridges the knowledge gap between urban and rural population. Telecenter in a rural area is a common place where e-services can be accessed i.e, it includes services like women livelihood training programs, tele-medicine through a tie up with experienced consultation in medical sciences, e-education where tutor delivers lectures from a remote place, virtual agriculture for interactive farmer's advisory services, awareness and capacity building programs like "Rural career buzz" etc. Hence internet connectivity is essential for successful implementation of these services, which can be wired or wireless. As wired connection is quite typical to lay down for longer distances and costly, we prefer wireless connection in our comparision of wireless technologies. Traditionally, CorDECT technology, a Wireless local loop (WLL) system is used in n-logue telecenter for e-applications. As a result of low datarate (72 Kbps), it is not widely used. Among different wireless technologies available, in this paper, we are considering Wifi, VSAT, Wimax and CDMA450 for deployment at a telecenter in rural areas.

Problem Definition: The network establishment of wireless technology particularly in rural areas face challenges because of ambiguity in choosing appropriate wireless technology[1]. Hence selection of best technology, which suits best for rural areas in concern to the applications like e-education, telemedicine, virtual agriculture etc is prominent.

Challenges to face for telecenter implementation in rural areas are: i. Remoteness leading to high startup cost[1], ii. Low population density leading to limited usage, iii. High operating cost, iv. Technology moves fast.

These different problems are to be considered to select a wireless technology, where one will be advantageous over other if a single aspect is considered.

For instance, a general problem encountered in real life situation is "Buying a fruit in a market", where priorities of selecting a fruit vary when parameters like taste, cost, nutrition are taken. In the similar way, Wifi is advantageous in terms of affordability, VSAT with global coverage, Wimax with high data rates, cellular networks with more deployments and availability. Hence, selecting optimal wireless technology for telecenters is crucial.

Wireless Technology Attributes: In this paper, optimal wireless technology for a telecenter is chosen among Wifi, VSAT, Wimax and CDMA450. Wifi (Wireless Fidelity) commonly known as wireless LAN with 802.11 as its IEEE standard and different types of Wifi are 802.11 a/b/g/n. VSAT (Very Small Aperture Terminal), a type of satellite communication which offers borderless communication within the coverage area and is accessible to remote areas. It has indoor and outdoor unit. Indoor unit will be placed in a telecenter to access e-services and Outdoor unit will be placed outside telecenter with a link with outdoor unit at master node of the VSAT network.Wimax (Wireless Interoperability for Microwave Access) with 802.16 as its IEEE standard. Its major characteristic is processing the adoption of advanced radio features in a manner and reduce the costs of all radio[2]. CDMA450 (Code division Multiple Access), is a form of CDMA2000, that operates in 410-470 MHz cellular band. It uses same air interface as CDMA20001x but operates at 470 MHz[3]. It has simpler spectral licensing, as this frequency is previously allocated to NMT450 in most of the countries, which is presently inoperational. For comparision of the above technologies, we are considering many qualitative and quantitative attributes such as technical, social, environmental and economical aspects as shown in figure 1.

1. ***Technical aspects***
a. Quality
i. Throughput, Latency, Jitter, Security, Spectrum
b. Technology setup
i. Ease of set up, Maintenance, Technical Sustainability, Coverage
2. ***Social aspects***
3. ***Environmental aspects***
a. Radiation
b. Effect of climate
4. ***Economical aspects***
a. Capital expenditure (Capex)
b. Operational expenditure (Opex)

Table 2 and 3 represents quantitative and qualitative comparision of attributes respectively for the 4 wireless technologies. These parameters are taken from measurements at telecenter, networking experts and theoretical studies.

Network data rate refers to the volume of data that can flow through a network. Latency is the roundtrip delay a message takes when it is sent from source to destination. If typical value of latency is minimal i.e, amount of packet delay is less, then information transfer for audio and video applications will be very appropriate. It is measured using ping response as shown in figure 8, between client and server nodes. Average latency value is considered from few measurements. Ideally, delay between packets in a message should be uniform, but it is not practically observed. Jitter is non-uniform packet delay. We used Jperf, a useful open source network performance measurement graphic tool for measuring throughput and quality of network link. This tool utilizes TCP and UDP[4]. TCP is used for measuring throughput. UDP is used for measuring jitter.

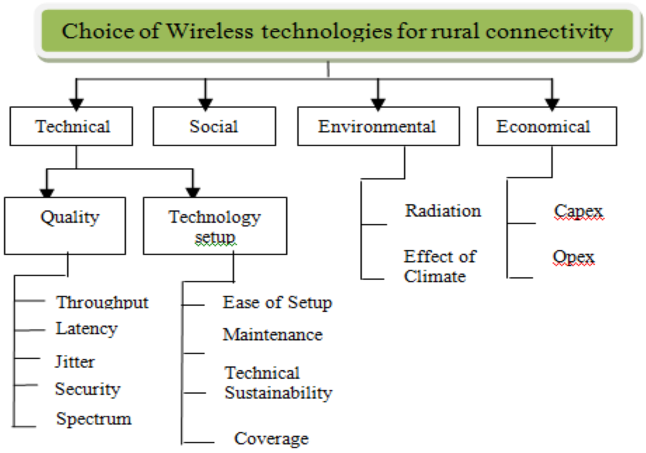

Figure-1
Hierarchy tree of technology attributes

Security includes provisions and policies adopted by networking hardware and administrator to prevent and monitor unauthorized access. Spectrum refers to radio portion of the electromagnetic spectrum. It can be licensed or unlicensed. Technology setup includes ease of deploying the network, it's maintenance with respect to technicians availability and access to hardware during deployment failure. Since radiation exists for a long time, it has the capacity to inflict damage upon anything exposed it. Hence, we considered effect of radiation as an Environmental aspect in our paper. This includes the effect of radiation produced from deployments on environment. Climate is considered, as hardware might be effected with exposure to rain. In this paper, Capex (Capital Expenditure) of a telecenter includes network establishment costs for surveying, price of equipment, furniture and installation costs. Opex (Operational Expenditure) of a telecenter includes wages to network expert for maintenance of network connections, electricity bills and cost of transmission media etc

Table-1
Quantitative comparision of attributes (approximate)

Alternatives/Attributes	802.11b	CDMA450	802.16a	VSAT
Bandwidth	20MHz	450MHz	25MHz	200KHz
Latency	8ms	70ms	40ms	500ms
Jitter	4.9ms	14ms	10ms	60ms
Spectrum	2.4GHz 5GHz	450MHz	2-11GHz	12-14 GHz
Coverage	100m-1km	17km	50km	38,000km Geostationary satellite
Datarate	11 Mbps	2.4 Mbps	75Mbps	2 Mbps

Table-2
Qualitative comparision of attributes(approximate)

Alternatives/ Attributes	**802.11b**	**CDMA450**	**802.16a**	**VSAT**
Ease of set up	30-40 days	45-50 days	30-40 days	20 days
Maintenance	License exempt bands are increasingly crowded	Cell breathing when users are more	Technicians availability is less	Troubleshooting makes low mean time to repair
Technical sustainability	Smart bridges, Cisco, BSNL etc	Lucent tech,Qualcomm,Huawei,ZTE,Nortel etc	Samsung, Motorola etc	Starband, iDirect, Romantis, Spacenet etc
Security	WPA+WEP	SHA-1,AES algorithm	Triple DES,RSAAES	Triple DES
Environmental concern	Loss of data transfer during rain	ISI and fading effects	ISI is comparatively less	Fading due to rain/snow
Capex	D	C	B	A
Opex	C	B	A	D

In capex and opex tabulated results A>B>C>D and RSA, DES, SHA-1, AES are encryption algorithms. Ease of setup is considered to be the case when equipment is ready to deploy.

Analytical Hierarchy Process: In this paper, we compared different wireless technologies like Wifi, VSAT, Wimax and CDMA450 using AHP (Analytical Hierarchy Process). AHP is a decision making algorithm developed by Thomas.L.Saaty in early 1970's. AHP can handle both qualitative (through representation of qualitative attributes in terms of quantitative attributes) and quantitative attributes[5]. It is used to derive ratio scales for pairwise comparisions.

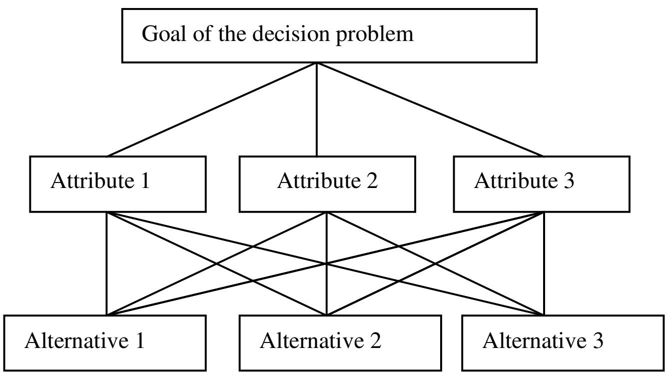

Figure-2
AHP hierarchy of goals, objectives and alternatives

Figure 2 is an example of AHP hierarchy tree when only 3 alternatives and attributes are considered. Quantitative attributes can be of cost or benefit. Cost attribute is that, maximum quantity of this attribute is bad for overall objective of the decision. For example, consider the electricity consumption, minimum electricity consumption is benefit. In this paper, latency, jitter, capex and opex are cost attributes. Benefit attribute is that, maximum quantity of this attribute is good for objective. For example starting an industry with the goal of upliftment of the people below poverty line, then employment attribute is benefit. So, increasing the number of the employees is beneficial with respect to overall objective. Data rate, coverage are benefit attributes in this paper.

Pairwise comparisions are fundamental in the use of AHP. The intangibles or qualitative attributes have no absolute measurement values as like quantitative attributes. So, to give priorities to the qualitative attributes, it is important to have a value. These values are obtained by pairwise comparision of these attributes with a higher level criteria or objective. Generally, in comparision of two attributes, an expert says the judgements as “The attribute 1 is more important than this attribute 2”. To scale this type of judgements, T.L. Saaty developed fundamental scale as shown in table 3. The number given for attributes comparision depends on the intensity of importance of one attribute over another attribute.

Table-3
Fundamental scale of absolute numbers[5]

Intensity of importance	**Definition**	**Explanation**
1	Equal importance	Two activities contribute equally
3	Weak importance	Slightly favor one activity over another
5	Strong importance	Strongly favor one activity over another
7	Very strong importance	Very strongly favor one activity over another
9	Absolute importance	Absolutely favor one activity over another

2, 4, 6, 8 are intermediate values between two adjacent judgements.

For example, if the expert says ‘A’ is weak important over ‘B’, then according to the Saaty’s fundamental scale we represent it as, A is three times B (A=3B or B=1/3 A). In the same way ‘A’ is very strong important over ‘C’, we represent it as A is seven times B (A= 7C or C= 1/7 A). In the same way ‘B’ is moderately important over ‘C’, it is represented as B is 4 times C (B= 4C or C= 1/4 B). With the similar method of ranking, AHP matrix obtained for the throughput attribute for 4 different wireless technologies is shown below. Likewise, AHP matrices has to be filled for all the qualitative and quantitative attributes chosen for alternatives.

	Wi-Fi	VSAT	Wimax	CDMA-450
Wi-Fi	1	5	1/6	4
VSAT	1/5	1	1/7	2
Wimax	6	7	1	7
CDMA450	1/4	1/2	1/7	1

(a)

	Wi-Fi	VSAT	Wimax	CDMA 450
Wi-Fi	1	5	1/6	4
VSAT	1/5	1	1/7	2
Wimax	6	7	1	7
CDMA450	1/4	1/2	1/7	1

(b)

Maximum eigenvalue (λ_{max}) has to be calculated for pairwise comparision matrix. Consistency index (C.I), defined as C.I = $\frac{\lambda_{max} - n}{n - 1}$, where ‘n’ is the size of the matrix[6]. The value of consistency index must be less than 0.1 i.e, it is valid for and consistent judgements. If it is greater than 0.1, pairwise comparision matrix should be solved again. Similary, C.I of all attribute matrices should satisfy the condition. Obtain weighted matrix for each attribute in all the levels[10]. Then, calculate global priority matrix by multiplying last level weighted attribute matrix with parent matrix (upper level matrix). Now, compare alternatives with respect to attributes in the last level by pairwise comparision and arrive at weighted matrix (priority matrix). Finally, to arrive ranking of each alternative, multiply the weighted matrix of attributes in the last level with the priority matrix. The following is the flowchart representing the Analytical Hierarchy Process.

Case Studies: KVK Byrraju Foundation: KVK Byrraju Foundation is Wi-Fi network based telecenter which connects 32 villages in East and West Godavari districts of Andhra Pradesh. In its telecenter Ashwini, it offers e-serivces like e-education, telemedicine, e-livelihood and virtual agriculture. It uses 802.11 b/g linked wireless technology to provide a 2Mbps bandwidth to each of the 32 villages[7]. In KVK Foundation,village nodes form a cluster with master nodes i.e, places where expert delivery is provided. There are 3 master nodes in KVK foundation. This was deployed by team of Prof.Bhaskaran Raman, IIT Bombay[8].

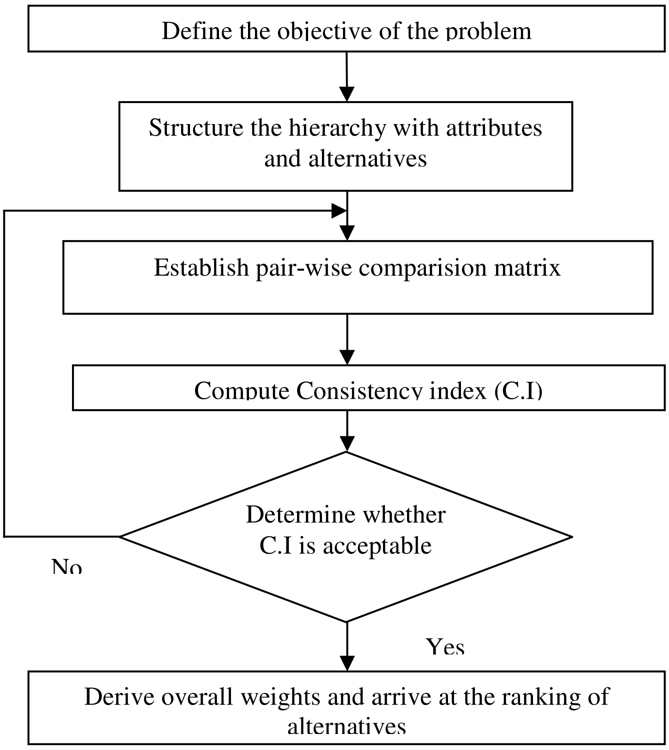

Figure-3
Summary of AHP method

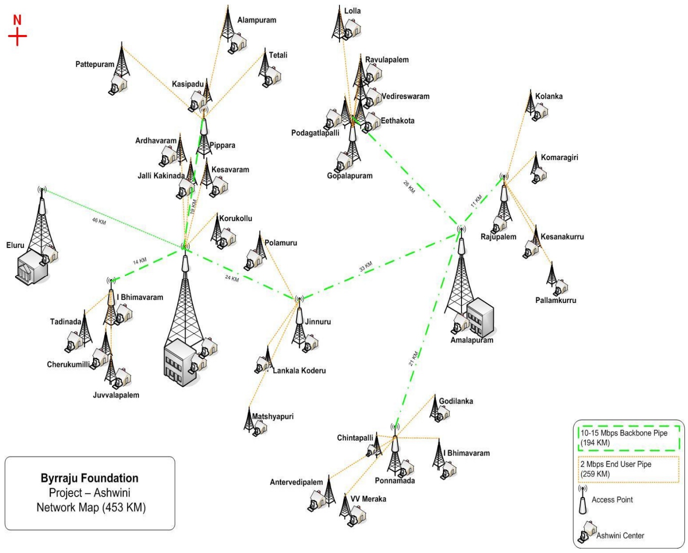

Figure-4
32 nodal network of Ashwini

Figure-5
Ashwini telecenter

Village Resource Center (VRC): VRC was established with VSAT network. Main goal of VRC is to solve needs of rural areas and to bridge the knowledge gap between urban and rural[9]. ISRO has initiated the VRC concept which offers e-services and meets the goals of a telecenter. Main nodal center of VRC is at NRSA, Balnagar, at which we learnt about its VSAT network with assistance of Dr.Saindranath Jonna, Project manager of VRC. VSAT deployment of VRC is done by team of Anil Kushuwaha (Mahdibagh Computers-VSAT installation), Pune.

Figure-6
VRC at NRSA, Hyderabad

Results and Discussion

Technical attributes like datarate, latency and jitter are measured between KVK foundation allavaram node and bhimavaram nodes in East Godavari district, Andhra Pradesh using Jperf tool. An IP address of two computers, enabled with Ashwini Wifi network at different nodes, are taken as client and server. The following are the results obtained with Bhimavaram as client and allavaram node as server.

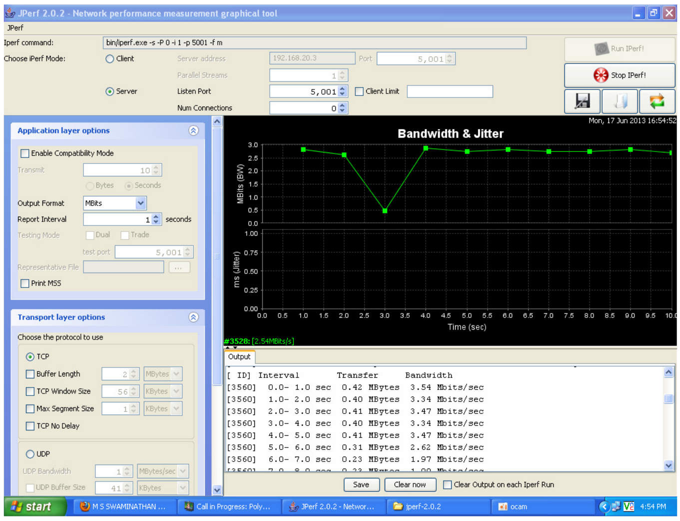

Figure-7
Bandwidth measurement with Allavaram as server

From figure 8 of jitter measurement, it can be noted that delay between packets is changing continuously with respect to time. Hence, average jitter of 4.9ms is observed from the measurement.

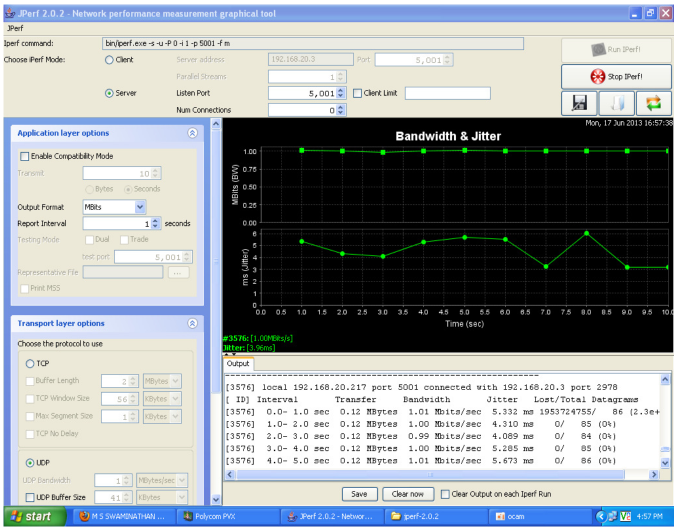

Figure-8
Jitter measurement with Allavaram as server

Latency is measured using ping response between bhimavaram and allavram nodes of Ashwini network, KVK Byrraju foundation. Ping response measurement is shown in figure 9 and average latency of 8ms is observed in network.

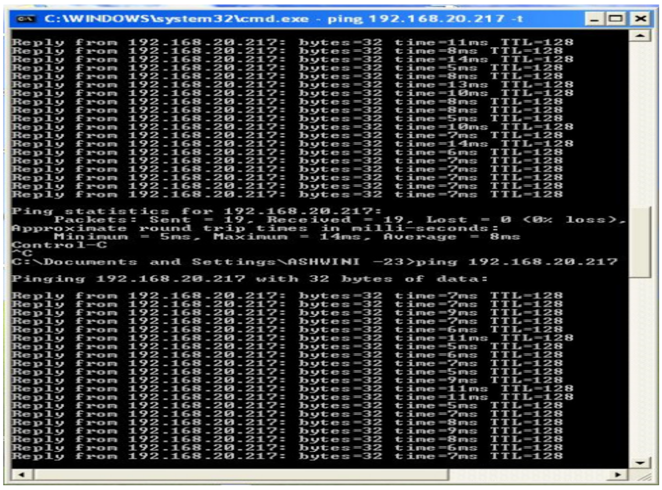

Figure-9
Latency measurement with Allavaram as server

AHP Analysis in Mat Lab: As AHP analysis (finding eigen vector, normalization, consistency ratio etc.) is cumbersome to solve manually for larger nxn matrices, we analyzed it in mat lab package. This mat lab package includes description of problem, number of alternatives, attributes, sub-attributes etc. Details about number and their names has to be manually entered. Further, from inputs of pairwise comparision matrix elements entered, maximum eigen value and consistency index will be computed. If C.I is greater than 0.1, it will ask to enter matrix elements again. Similar procedure will be done for all attributes. Then, from computed weight vectors, ranking for alternatives will be obtained as output in mat lab. Figure 9 shows the piechart ranking result obtained for Wifi, CDMA450, VSAT and Wimax.

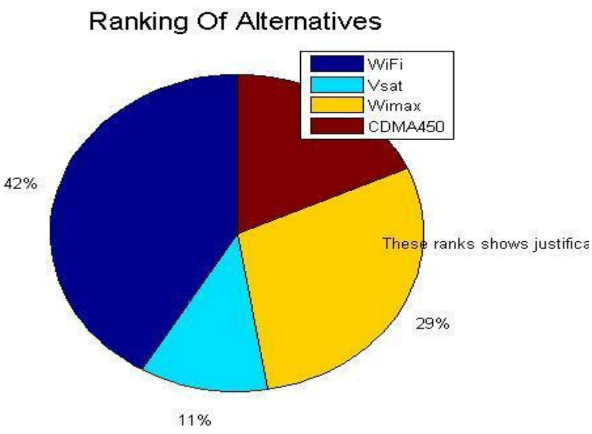

Figure-9
Pie chart result of AHP in Mat Lab

Applications and Future Work: The findings of the study on "Choice of Wireless technologies" will have profound effect on so many areas. This study will be beneficial to the Information and Communication technology (ICT) in bridging the digital divide, thus promoting rural areas through development in the area of telecommunication by establishing telecenters for e-applications. It resolves the ambiguity in choosing the optimal wireless technology by means of many qualitative and quantitative attributes and analyzing it in AHP. Future work includes working on Capex and Opex numerical values to make it as a quantitative attribute in AHP and study on 3G network expansion to deliver e-services for rural people, instead of CDMA450 technology. We would like to work on combination of two technologies like Wifi and VSAT which offers the advantages of both in terms of datarate, affordability and coverage.

Conclusion

From different qualtitative and quantitative attributes considered for comparision of wireless technologies, ranking is obtained from AHP analysis in matlab. Percentile raking of Wifi (42%), indicates that Wi-Fi is the preferred wireless technology to be deployed at telecenters in rural areas. Wifi is suggested solution, as it is possessing enough datarate, coverage area to connect multiple village nodes, extension of Wifi equipment utilization in market, troubleshooting guidance and affordability to run e-applications in rural areas. VSAT (11%) is not much preferred as it has poor datarate, latency and jitter values, which is not quite suitable for audio and video applications.

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