COMPARATIVE STUDY OF BACKHAUL OPTIONS FOR COMMUNICATION AT SEA

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ABSTRACT: Current maritime communication is mostly using the legacy VHF radio, which provides line of sight audio voice communication. It is known that satellite communication is the only option for secured long distance communication at sea. However it is not affordable for fishermen because of the substantial capital investment involved in launching the satellites to orbit. This work studies existing wireless technologies such as 2G, 3G, Wi-Fi, WiMAX, Cognitive Radio and LTE based on cost, communication range, operating frequency, vendor availability, bandwidth requirement, data rate requirement and latency. A utility function is computed based on the factors and finally a cost effective backhaul technology option for communication at sea is proposed for use by Indian fishermen.

KEYWORDS: 2G, 3G, LTE, Wi-Fi, WiMAX, CAPEX, ISM

INTRODUCTION

There are about 2000 coastal villages in India whose community is mainly involved in small-scale fishing, based on traditional methods. It provides the livelihood to a large number of economically backward people in the country. In this regard, the livelihood of millions of fishermen is governed by the availability of reliable and low cost technology solutions. About 90 percent of them work in boats which are poorly equipped in terms of security, communication and navigation. Thus there exists an imperative need for an economical communication platform for fishermen that help them to communicate in critical and non critical situations, between ships and various vessels in the sea as well as with the shore to meet their business and personal needs.

The communication systems employed by the maritime users are still the legacy (Very High Frequency) VHF radio in broadcast mode which has line-of-sight coverage. In addition to this, fishermen use cellular network for private calls, however, its coverage is limited to a maximum of 15-20 km from shore [1]. Due to economic constraints, further extension of mobile coverage into the sea is not feasible for service providers. Satellite communication could be used beyond cellular coverage. But because of the high cost, latency and jitter, it is not suitable for economical real-time applications at sea. In short, the above solutions are not feasible due to their critical challenges. Hence, it is imperative to provide communication infrastructure for coastal regions of India to connect with them while they are out at sea. This envisages the prerequisite of low cost hybrid terrestrial and marine based solutions. However, in order to realize such solutions there are considerable challenges.

An application infrastructure is required to support mobility of about 10Km/hr. The primary requirement for the communication platform is to support voice calls, text messaging and data transfer. A voice application could tolerate a delay up to 200ms without degrading the sound quality [2]. The choice of mobile broadband standards to deploy for the communication platform at sea should have low cost, responsive vendor support, good transmission range, reasonable data rate support, low bandwidth requirement with low latency and good mobility support. Current literature does not have any such deployments, meeting the identified constraints. To address this communication challenge, we need a technological alternative. The main objective of this paper is to investigate various advanced communication technologies and protocols, in both licensed and unlicensed spectrum and to come up with a cost effective technological option for backhaul. We evaluate various technologies in terms of cost (including the spectrum licensing cost and capital expenditure (CAPEX)), robustness, good backhaul support, quality coverage etc.

PROBLEM DESCRIPTION

The identification of various feasible backhaul technology options to carry the voice/data traffic between the access node deployed in the boat and the base station deployed on the shore and connected to the service provider network considering various factors such as cost, vendor support, data rate, range of transmission, bandwidth requirement, etc. The problem can thus be formulated as follows:

1. Economical long distance, private communication is not possible at sea currently.
2. Fishermen usually go up to 63 nautical miles from the shore and spend several days together at sea [1].
3. Maritime communication is mainly using legacy VHF operating in broadcast mode.
4. The range of VHF radio and cellular networks is limited [1].
5. Some backhaul technology capable of long distance communication is required to carry the traffic from the boat to shore or between boats.

RELATED WORK

Chang et al. [2] discuss about various dimensions of the two 4G technologies, namely, LTE (Long Term Evolution) and WiMAX (Worldwide Interoperability for Microwave Access). The comparative study includes technological aspects such as modulation schemes employed, access methods used, mobility support, multi user support etc for each of the technologies. It also points out merits and demerits of two technologies such as vendor support, existing customer base, supported data rate, future trends, etc.

In “Ref [4], [6]” Lin et al. are comparing the performance measurements of three cellular technologies, TD-LTE (Time Division Long Tern Evolution), WiMAX and 3G systems. The study is mainly focused on cellular technologies. Kabir et al. [3] had done a comparative study of suitability of Wi-Fi and WiMAX for building Wireless Access Infrastructure w.r.t the parameters such as radio transmission modulation technique, efficiency, maximum coverage range, security, mobility management market comparison and quality of service. The author establish that WiMAX is better compared to Wi-Fi under the constrains discussed in the paper. But WiMAX being a sun setting technology [5] and Wi-Fi being a widely accepted technology that matured over the past decade, wins the war .Currently researchers are behind the Wi-Fi to improve various aspects such as the data rate ,the range of communication , medium utilization etc. Wi-Fi has matured to the point that it is deployed for many long distant applications and mission-critical applications [10], [11]. In “Ref .[7], [8]” Wang et al., surveys about the various advancement in cognitive radio networks and emerging cognitive radio applications in the field of communication.

Performance comparison of CSMA/CA and TDMA in long distant Wi-Fi:
The standard 802.11 MAC protocol uses contention-based CSMA/CA channel access mechanism which was originally designed for short range communication. The key reasons for this detrimental performance are highlighted by Patra et al., [9] as

• High probability of packet loss,
• Inefficient acknowledgment mechanism,
• Possible interference.

Though Wi-Fi based Long Distance (WiLD) [9] networks offer an economical network connectivity solution, the actual deployments of such networks face many challenges. This is due to elementary protocol shortcomings such as low link utilization due to the 802.11 link-level recovery mechanisms, recurrent collisions due to the failure of Carrier Sense Multiple Access/Collision avoidance (CSMA/CA) at long distances and inconsistent link through put due to exterior Wi-Fi interference [10],[12]. WiLD network experienced very high and variable packet loss due to external interference as well. Transmission Control Protocol (TCP) flows constantly experience timeouts and flow barely progresses. Patra, Rabin K et al., [11]explain various measures adopted in WiLDNet, which uses the standard Wi-Fi network cards with modified 802.11 MAC protocol. To handle losses and get better link utilization, WiLDNet used an adaptive loss-recovery mechanism using forward error correction and bulk acknowledgments.

For larger distances, the contention based CSMA MAC degrades Wi-Fi performance and throughput. This is because of the collision of packets due to hidden node problem associated with contention based CSMA MAC. To overcome this, CSMA MAC is replaced with TDMA MAC so that the packet transmission follows an agreed time schedule, which reduces the packet collision and avoids the hidden node problems in long range communications [9]. The proposed solutions are to

• Extend the ACK timeout
• Block ACK and
• TDMA

In [13] the authors are performing a research on appropriate wireless technologies that can provide low cost, rapidly deployable connectivity solutions for low user density regions. The paper compare and contrast the requirements and performance of low and high user density regions using point to point long range wireless network setup using directional antennas. In [14] Subramanian at el., discuss about the implementation of very long distance Wi-Fi network in various part of the globe such as India, Ghana, etc as part of WiLD network. The paper also comparing the implementation of a mesh network and the WiLD .The paper [14],[15] discussing about the challenges such as issues at the medium Access Layer or MAC layer, various non technical challenges, loss recovery mechanisms to enable the Wi-Fi for long distant communication.

The paper [16] presents experimentation of setting up a high quality 2.4 GHz wireless LAN over sea. Space diversity employed in conventional microwave trunk lines, has been adopted in this Wi-Fi experiment, which uses two antennas and two receiving circuits inside the same receiver. The installed network has five wireless links and the longest link is 11.3 km long. They proposed the space diversity to lower the unfavorable affect of fluctuation due to tidal effect, in which two wireless LAN devices of different antenna heights are installed at one side of the longest link. In this experiment the communication end points are at land, at higher altitude and the communication is happening over the sea. The experiment also considered the sea roughness in the two path model and the height of the antenna for space diversity while deployment. This work motivates the ability to use Wi-Fi for communication over large distances. This work differs from current work in the sense that one end is always at sea and the transmission high site at the shore.

The paper [17] discuss about I-WiMAX (Intelligent WiMAX), based on 802.16e and SR (smart radio), a new maritime communication systems using Adaptive Beam forming (AB) and Distributed Beam forming (DB) techniques. This technique helps adopting AB where the same spectrum can accommodate more users by directing the main beam towards preferred users by setting antenna pattern nulls towards the undesired. DB methods different beams are directed towards different required directions at the same time. With the AB and DB techniques, dependable I-WiMAX links can be set up for long distances, with increased optimum spectrum use and fewer infrastructures. WiMAX mainly operate in licensed spectrum and is a sun setting technology. But the techniques Adaptive Beam forming (AB) and Distributed Beam forming (DB) could be made use in the technology chosen for long distant communication to extend the range of the communication.

Most of the mobile base stations across the globe are connected using point-to-point microwave technologies [18]. Microwave technology provides an unquestionable solution for mobile operators for their evolving networks to meet next-generation challenges and form an ideal transport solution. Microwave radio transport offers the ideal blend of scalable high-capacity IP transport with a cost efficient solution to enable operators to maintain profits and delivering the services that consumers increasingly desire. Microwave technology has greatly evolved to accommodate the advantage of the IP into the backhaul network to deliver higher capacities, increased frequency efficiency, increased flexibility, and finest cost by combining a set of features to enable gigabit transport speeds [18].

Zaidi et al. studied various backhaul options for broadband communication over sea between point to point links [17]. Paper presents a comprehensive survey of various possible solutions to provide wireless backhaul PTP links for broadband communication over sea which includes microwave links, satellite communication, LTE, fiber optics, etc. Various study of propagation effects and characterization of electro magnet waves over land and maritime scenarios such as ducting effects, troposphere radio propagation etc are studied in [28],[29],[30],[31] and [32].

Limitations of current studies

Current studies in [17] are carried out to compare the performance of various Cellular networks such as 2G, 3G and 4G technologies over land and [19] satellite to be used as a backhaul for cellular network, which is an expensive option . In [3] comparative study of suitability of just Wi-Fi and Wi-Max technologies in setting up Wireless Access Infrastructure over land is carried out.

In short the existing studies are currently focusing on comparing one or two wireless technologies such as CR, LTE and Wi-MAX or Wi-MAX and Wi-Fi etc [4], [5], [6], [7]. The aim of this exercise is to study about the various technological alternatives not limiting to just cellular network. Most of the existing studies are done between fixed points over land or over sea with fixed end points located on land. In our study, we are considering land to boat and boat to boat links.

APPLICATION SCENARIO

A survey conducted with local fishermen reveals that, they travel with an average velocity of 8Km/hr for fishing and use VHF radios to communicate information like location, fish availability, route info etc among the peers. However, in case of exigencies like accidents at sea, fuel exhaustion, medical emergency, collisions and sinking of vessels, harsh weather conditions etc, fishermen need to communicate with authorities to seek assistance. If the authorities are not within the one hop distance of the boat, currently communication is established via manual message passing with the help of neighboring boats at sea using VHF radio. Due to this manual multi-hop communication, there is a delay in getting assistance and support during critical situations. In order to resolve these challenges, the fishermen should have some reliable connectivity between shore and the boats to establish the communication. Currently the service of the cellular providers is available only near the sea shore. Hence, a reliable communication to the shore is still a dream for the fishermen at sea.

Before proposing a suitable backhaul candidate by analysis and evaluation of different communication technologies, it is necessary to understand the use case scenario. Usually, fishermen's boats go individually for fishing, but they can be seen in clusters as shown in Fig. 1 near areas of fish abundance. If we can establish connectivity to the cluster of boats, we can extend the communication range far out into the sea.

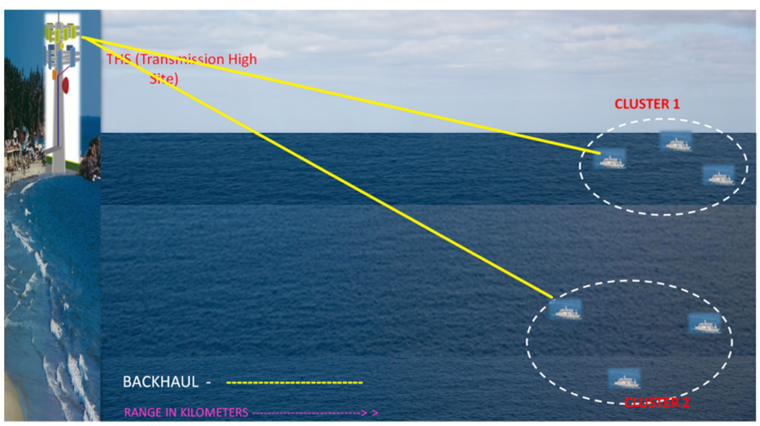

Figure 1 : Layout of Communication Architecture

Fig. 1 shows the proposed scenario, wherein the Transmission High Site (THS) is located in the shore .The base station is mounted in the THS with directional antenna facing the sea side .Boats usually go for fishing individually but they are seen as several groups, out at sea. To provide communication, backhaul connectivity is required among the clusters. We investigate several wireless technologies to backhaul the voice/data between the THS and the boats. In this use case scenario we consider the factors such as spectrum licensing, CAPEX (Capital Expenditure), vendor support, data rate, range of transmission, channel bandwidth requirement and mobility ,as the parameters for evaluating the utility score for each of the candidate technologies. Fig. 2 shows the flow chart of the study and evaluation of identified technologies w.r.t the identified parameters.

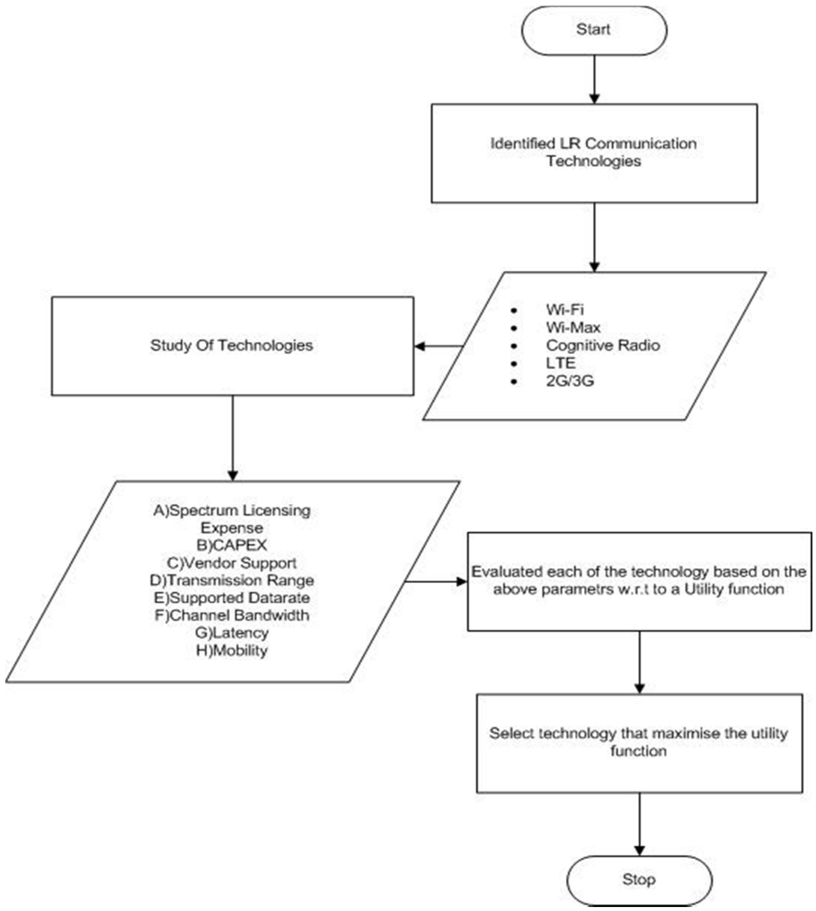

Figure 2: Study and Evaluation of Backhaul Technologies

A brief description of the factors of interest is given below.

Spectrum licensing expense
Spectrum being a sparse resource, there is a cost associated with it. Cellular technologies like LTE and WiMAX work in licensed spectrum where as technologies like Wi-Fi, Bluetooth, work in the unlicensed Industrial Scientific and Medical band(ISM).2.4GHz and 5GHz belong to ISM bands.

Advantages and Disadvantages of 2.4 GHz
- Worldwide Unlicensed Band.
- Three non overlapping 20MHz channels (1, 6, 11)

- Too packed band with a lot of interference from cordless phones, Wireless Router, etc
- 40MHz wide channels not suggested or recommended for 2.4GHz.

CAPEX (Capital Expenditure)
CAPEX is the capital expenditure involved in setting up the infrastructure. It includes the installation and maintenance of software and hardware. It is always appreciated to have a low CAPEX value.

Vendor Support
The demands of wireless technologies are high as the use of mobile devices and people accessing internet has increased. The greater the acceptance of the technology, the larger will be the vendor support. Greater vendor support means more market competition. Hence, multiple choices for the products as well as the supporting products will be available in the market at a lower price.

Transmission range
It is the distance or the area serviced by deploying the base station. The technology that offers larger transmission range will be the more preferred one.

Supported Data Rate
The specification of the technology should at least support the data rate required to carry out voice calls, text as well as data at the maximum possible transmission range. A data rate of 128 kbps may be acceptable.

Bandwidth Requirement
It is expected that the technology should serve the user with the least available channel bandwidth.

Delay/Latency
The specification should offer lower delay/latency in receiving signal. Lower the delay, better the user experience especially for audio and video streams.

Mobility
The mobility defines the capability of a technology to support a moving device. Greater mobility implies, faster moving objects can be a part of the network and could be serviced by the infrastructure. For example, WiMAX and LTE specification supports mobility of around 350 Km/hr .i.e., a person moving in a train should be able to connect to LTE or WiMAX network and access the network seamlessly [2].

Discussion of candidate technologies
In this section we discuss each of the candidate technology such as WiMAX, LTE, Wi-Fi, CR and 2G/3G with respect to the identified parameters discussed in Section IV.

WiMAX
IEEE 802.16 standard, also known as the WiMAX standard, provides both fixed and mobile broadband access and is a technology for last-mile wireless broadband as an alternative to cable and DSL [2][3]. WiMAX has the capability to maintain dedicated links and supports VoIP services with high speed and reliability. WiMAX Forum, which certifies interoperability of WiMAX products from various vendors, is a consortium formed by companies from the computer and telecommunications industries [4]. The latency requirement in WiMAX specifications supports

voice applications. WiMAX supports mobility up to a speed of 350 km/h .i.e.; a travelling person in a train could be connected to a WiMAX network. IEEE 802.16j standard supports relay stations, which are comparatively cheaper and easy to install. WiMAX architecture supports base stations connected to the internet and uses relays to extend the range and to relay back the wireless data to the base station.

The future of the WiMAX is a matter of debate. WiMAX specification has not provided an open standard for the interface to connect to the core network. WiMAX base stations need an interface to connect to the Access Service Network (ASN) gateway that links to the IP's core network. This interface is called R6 and not in the scope for the WiMAX standard. With the wide spread acceptance of LTE, some telecommunications companies have moved away from WiMAX implementations. Companies like Alcatel-Lucent, Cisco etc., announced that they will discontinue providing WiMAX base stations and will concentrate on radio agnostic IP core solutions [5],[6] and [7].In short WiMAX specification supports better data rate and offers good coverage. It also supports channel bandwidths of 5, 10, 20, or 40 MHz. Delay or latencies are well within the limits to support the voice and data. It also supports mobility up to 350 Km/hr[3] . But it operates in licensed spectrum and the expense in setting up the infrastructure is at the higher end. i.e., the licensing expense and the CAPEX are high. Also WiMAX is considered a sun-setting technology with the wide acceptance of LTE, a cellular 4G technology developed by telecommunications companies who would choose which technology to deploy [2].

LTE

LTE employ orthogonal frequency-division multiple access (OFDMA) in downlink and single carrier frequency-division multiple access (SC-FDMA) for the uplink. Using SC-FDMA the LTE uplink signal achieves highly efficient signal transmission and power savings without compromising system flexibility or performance [2].LTE, like any other cellular network supports mobility. It supports a speed of up to 350 km/hr. LTE supports QOS by reserving bandwidths for user access. The bandwidth reservation is achieved by using frames. LTE divides the time into frames of 10 ms and which is again sub divided into 10 sub frames of 1 ms each. LTE uses a concept called switch point, which will switch between the downlink and uplink. This method offers a more dynamic way of allocating Traffic with little delay, since a cell phone conversation could have an equal amount of traffic going from one end to the other[4].

LTE specification was developed by telecommunications companies, who decide which technology to go with. For LTE, the patent pooling is done by several licensing management companies. This leads to lower royalty rates for the products. LTE supports variable channel bandwidths, i.e., 1.4, 3, 5, 10, 15, 20 MHz bands [5], [6]. Long Term Evolution (LTE) and Worldwide Interoperability for Microwave Access (WiMAX) are two major technologies expected to provide higher throughput and lower transmission latency for mobile users with acceptable mobility [2, 20].To summarize, LTE is an emerging technology, it is yet to attain a strong vendor support. Being a cellular technology, it offers coverage of around 40 km over land. Though LTE has a good handle over the factors such as support for variable channel bandwidth, low latency, better data rates and mobility [20], the licensing expense and high CAPEX shadows the merits of the technology.

Cognitive Radio

Cognitive Radio (CR) [25] is considered as the solution to the underutilization of the radio spectrum. The key feature of the technology is that, the radio's operating characteristics adapt to the real-time conditions of the environment thereby enabling flexible, efficient and reliable spectrum usage. CR has the potential to utilize the large amount of underutilized or unused spectrum in an intelligent way for secondary users (SU) while not interfering with the primary users (PU) or licensed users.

The IEEE 802.22 defines a standardized air interface based on CR techniques for the opportunistic access of TV bands on a non-interfering basis. The 802.22 system supports total PHY data rate of 18 Mbps in a 6 MHz TV channel. The transmission range can go up to 100 Km if no limit is set on power .Current specified coverage range at 4 Watts CPE EIRP is 33 Km. IEEE 802.22 offers a much better coverage than other 802 standards, which is primarily due to its higher power and the favorable propagation characteristics of TV frequency bands. Cognitive radio is a promising technology having the advantage of longer transmission range which works in potentially license exempt spectrum. But since the technology is just emerging, the vendor support is very less. Hence the CAPEX is too high. Cognitive radio technologies can boost existing networks to dynamically use the newly available spectrum either in the access or backhaul parts of their networks [8], [9].

2G/3G

GSM and CDMA offer voice and limited data services, and use digital modulation for improved audio quality. 2G and 3G are the most widely used cellular standards where 80% of all mobile phone activity takes place. With the advent of technologies such as 2.5G, 2.75G and 3G, the cries of ever increasing demand for higher data rates have hit the roof. While packet data was introduced in 2G, higher data rates and better data services were brought by 3G. 2G supports large amount of calls in the same radio bandwidth and its low power consumption enhances battery life in cellular phones [19]. This technology works in licensed spectrum and it provides mobile coverage over a distance 4-40kms over land. The transmission range of a cellular base station over water bodies is found to be less because of the multiple reflections and ducting effects in sea surface. It provides a data rate of 2 Mbps to maximum of 28 Mbps. But compared to 4G, data rate is inferior. Density of cellular users will be comparatively lesser in the sea and hence, CAPEX incurred by Telecom operators is not recoverable though the solution is technically feasible. This restriction makes telecom operators reluctant to deploy the required infrastructure at seashore.

Wi-Fi

Conventional networks based on cellular, telephone, satellite or fiber is regarded as expensive options in sparsely populated, low-income rural regions. Cellular and WiMAX technologies necessitate a minimum user density to pay back the cost of the base station and these solutions focus on licensed spectrum. Wi-Fi is based on the IEEE 802.11 wireless local area network (WLAN) specification designed to work in license exempt ISM band [10]. Primarily it is designed to be used indoors at close range, for example in residential area or in office environment. Wi-Fi is a promising low-cost connectivity solution, and is increasingly deployed in developing nations around the globe [12].Wi-Fi networks provide users with seamless access to network resources from any place inside the coverage area. The main cost gains arise by employing the use of low cost off the shelf 802.11 wireless cards which operates in license exempt spectrum. The base stations and access points are lightweight and they don't need classy towers [11],[13], and [15]. For short range Wi-Fi communication, omni directional antennas are used and for long distance communication, highly directional antennas with about 24dBi gain are used in point-to-point communication mode. WiLD networks are able to achieve a communication range of about 100 Km [16].

IEEE 802.11n, commonly termed 802.11n, uses multiple antennas to increase data rates [24]. Wi-Fi 802.11n offers an enhanced network throughput and maximum data rate over prior standards by making use of MIMO technology. 802.11n offers a peak data rate of 600 Mbps. It works in both 2.4 GHz and 5 GHz frequency bands and supports frame aggregation techniques and MIMO concept [15].Major Wi-Fi vendors such as Ubiquity, Cisco, Siemens, D-Link, Aruba, etc, have rolled out solutions implementing all major amendments proposed in the 802.11n standard. Also companies like Airtight Networks, Air Magnet etc upgraded their Wi-Fi products to 802.11 n. This Wi-Fi standard supports high throughput, broad range, and better voice communication medium along with better mobility.

Though Wi-Fi Long Distance (WiLD) [9], [13] networks offer an economical network connectivity solution, the true deployments of such networks face many challenges. This is due to elementary protocol shortcomings such as low link utilization due to the 802.11 link-level recovery mechanisms, recurrent collisions due to the failure of CSMA/CA at long distances and inconsistent link throughput due to exterior Wi-Fi interference. WiLD network experienced very high and variable packet loss due to external interference as well. TCP flows constantly experience timeouts and flow barely progresses. Patra, Rabin K et al., explain various measures adopted in WiLDNet, which uses the standard Wi-Fi network cards with modified 802.11 MAC protocol. To manage losses and improve link utilization, WiLDNet employed an adaptive loss-recovery mechanism using forward error correction and bulk acknowledgments. For larger distances, the contention based CSMA MAC degrades Wi-Fi performance and throughput. This is because of the collision of packets due to hidden node problem associated with contention based CSMA MAC. To overcome this, CSMA MAC is replaced with TDMA MAC so that the packet transmission follows an agreed time schedule, which reduces the packet collision and avoids the hidden node problems in long range communications [14].

The attractiveness of the Wi-Fi is that it works in the unlicensed ISM bands and because of the wide market acceptance and the technology maturity; the CAPEX is very low for Wi-Fi. Wi-Fi offers a larger transmission range, when used with high gain directional antennas. It supports good data rate and supports channel bandwidth as low as 5 MHz [12].

Table 1 : Grade vs. Score

Grade	Score
Excellent	10
Very Good	8
Good	6
Fair	4
Mediocre	1

EVALUATION OF CANDIDATE TECHNOLOGIES

We have summarized the properties of various technologies in table “Table.3”. Each of the described communication technologies is rated for various factors. Spectrum licensing, CAPEX , vendor support, transmission range, supported data rate, bandwidth requirement, latency and mobility are the factors of prime concern in deciding the technological alternative for the application under consideration.

The tables "Table.2" and"Table.3" gives the comparison of technologies and the comparative grading of each of the technologies w.r.t, the identified parameters. Each technology is quantitatively evaluated against the identified factors based on the grade table" Table.1". The various grade considered are Excellent, Very Good, Good, Fair and Mediocre.

Table 2: Comparison of Technologies

Features/ Technology	**WiMAX**	**LTE**	**Cognitive Radio**	**2G/3G**	**Wi-Fi**
Spectrum Licensing	High	High	Low	Low	Low
CAPEX	High	High	High	Low	Low
Vendor Support	Low	Low	Low	High	High
Transmission Range	50Km radius	40Km radius	100Km radius	5-10Km radius	4-40Km radius
Supported Data rate	70Mbps	1-50Mbps	18Mbps(6MHz TV Channel)	100-400Kbps(2G), 5-5Mbps(3G)	600Mbps
Channel Bandwidth	20MHz (2.3,2.5GHZ)	40MHz (2.3GHz)	Varying	1.25MHz(3G) 200KHz(2G)	80MHz(2.3GHz) 580MHz(5GHz)
Delay/Latency	<100ms	<100ms	20ms	300-1000ms(2G) 100-500ms(3G)	<150ms
Mobility	120Km/h	450-500Km/h	114Km/h	120Km/h	Fast

For each of the identified parameter a weight and priority is assigned. As explained in the introduction section, the application is meant for the fishermen, so the cost is the most important factor in designing the system. Hence, the priority for the cost factor such as spectrum licensing as well as CAPEX has the highest value as in "Table.4". Hence cost factor is considered the most important parameter with priority as 3X.Vendor support is also important for feasible and economical deployment and operation of a network.

Hence next higher priority is assigned for vendor support. Transmission range has the next priority. This is followed by supported data rate, channel bandwidth and latency. Comparison of the various technologies is given in" Table.2".

Base on a detailed literature survey of related work, the identified technologies are graded on the various selected factors as shown"Table.3".

Table 3: Grading of technologies

Technology/ Feature	Spectrum Licensing Expense	CAPEX	Vendor Support	Transmission Range	Supported Datarate	Bandwidth Requirement	Delay/ Latency	Mobility
WiMAX	Mediocre	Fair	Good	Very Good	Excellent	Very Good	Very Good	Very Good
LTE	Mediocre	Good	Good	Very Good	Excellent	Very Good	Very Good	Very Good
Cognitive Radio	Very Good	Good	Fair	Excellent	Very Good	Good	Good	Very Good
2G/3G	Good	Good	Very Good	Very Good	Mediocre	Fair	Fair	Very Good
Wi-Fi	Excellent	Excellent	Excellent	Very Good	Very Good	Very Good	Good	Good

The boats are expected to move at a speed of less than 3 m/s. Hence, mobility is assigned the least weight say X.The factors, supported data rate, band width requirement and latency, are considered 1.5 times as important as the mobility factor i.e., 1.5X. Transmission range is considered twice as important as the mobility factor, 2X and vender support is 2.5 times as important as mobility factor, 2.5X. The licensing cost and CAPEX are assumed thrice as important as the mobility. The technology which acquires highest score based on the specified criteria will be the best candidate for long distance offshore communication.

Let w_i be the weight associated with each factor and $s_{i,j}$, be the score of the option j for the i_{th} factor.The sum of all weights is normalized to 1.

$$\sum_{i}^{k} w_i = 1 \quad (1)$$

Here k=8 (No: of decision making factors).

From (1) it follows

$$\sum_{i=0}^{8} w_i = 16X = 1 \quad (2)$$

$$X = \frac{1}{16} \quad (3)$$

Table 4: Factors and Corresponding priority

Factor (i)	**Priority**
Spectrum licensing cost	3X
CAPEX	3X
Vendor support	2.5X
Transmission range	2X
Supported Data Rate	1.5X
Channel Bandwidth	1.5X
Latency/delay	1.5X
Mobility	X
Total Priority	**16X**

We evaluate the utility of option j, u_j, which is the weighted normalized scores.

$$u_j = \sum_{i=1}^{k} w_i s_{i,j} \quad (4)$$

Table 5: Technology vs. Utility Score

Technology	**Utility Score**
WiMAX	5.81
LTE	6.19
Cognitive Radio	6.41
2G/3G	5.47
Wi-Fi	**8.75**

According to the evaluation using equations "Equations.1, 2, 3, and 4", results are tabulated in "Table.5". Wi-Fi secures the highest score. As we all know, Wi-Fi works in unlicensed band, which gives the advantage as there is no investment in spectrum license. Wi-Fi has matured over the years and also due to the wide acceptance of this technology, the cost of chipsets and equipment has come down. Added to it, most of the vendors support the Wi-Fi technology and lot of research is happening in this area.

CONCLUSION

Currently fishermen use legacy VHF radio for communication at sea; these devices provide line of sight communication. Satellite communication is an expensive option, which is not affordable for Indian fishermen. In our study, in order to build a seamless communication platform, various technology options were considered for the backhaul from cluster of boats at sea to the base station on the shore such as Wi-MAX, Wi-Fi, LTE, Cognitive Radio, 2G/3G etc. They were evaluated based on various factors such as cost, vendor support, transmission range, etc. Each of these technologies was scored based on normalized weighted sum of various factors. This analysis clearly shows that long distance Wi-Fi using TDMA is the best option for backhaul.

SCOPE FOR FUTURE WORK

Development of a prototype of the proposed system is planned using commercially available long range Wi-Fi equipment. Based on the results obtained from the prototype, link level and network level simulations will be carried out and appropriate models will be developed for propagation over the sea. Network level simulations will be carried out to analyze the performance and scalability of the network.

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