Optimizing Transmission Range and Speed for Nodal Interfacing for Emergency Applications in Delay Tolerant Technologies

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Abstract- Delay Tolerant Network (DTN) [6] is an upcoming technology that was introduced to facilitate communication in scenarios which lack intermittent connectivity [5]. These scenarios could be Military [8] and battlefields areas, health care units during disasters like earthquakes & volcanic eruptions, animal tracking in deep seas and terrestrial areas, etc. These applications have different scenarios and different requirements of performance metrics, but the commonality between all of them is that there is no support of a fixed network architecture. DTNs can work without a direct connection establishment between the sender and the receiver, like, in cellular communication, and can rather rely on simple short-range radios, like Bluetooth and ZigBee. This paper investigates the different technologies [12], ZigBee [18][19], Z-Wave [20][21], Bluetooth [15][22][23], Thread[17], Wi-Fi [25,27]based on their range of packet delivery and transmission speed, and finds out the suitable networking protocol in Military [8] areas and Deep Sea Oceans[10] such that the delivery probability and overhead ratio are better than Bluetooth technology. As Bluetooth's technology range and speed is less and we need a suitable technology whose parameters are better than Bluetooth technology, so this paper investigates the suitable technology which can be a good substitute for Bluetooth technology as in military areas and ocean monitoring the speed and range is of utmost importance. The scenarios and their corresponding parameters are simulated in the Opportunistic Network Environment [4] Simulator and the results are presented. The result after simulations show that Thread technology can be a suitable replacement for the existing Bluetooth technology in military areas. Thread technology reduces the number of relays by 12.14% than Bluetooth technology and giving the same delivery probability. Similarly results for ocean technology justifies that ZigBee can be a suitable replacement for the existing Bluetooth technology because of the increased transmission range that ZigBee offers and lesser number of relays than other technologies.

Keywords- Delay Tolerant Networks; Opportunistic Network Environment; ZigBee; Bluetooth; Z-Wave; Thread; Mobility Models; Military scenario; Ocean monitoring

I. INTRODUCTION

Delay Tolerant Network is becoming an increasingly popular technology as it can be used in environments where end-to-end connectivity is not possible. In DTNs, the messages are transferred from source to destination via intermediate nodes which uses the store, carry and forward approach. In our paper, we are taking two scenarios of the many applications for which DTN was introduced. First, we have implemented the military (tactical environments) [3] scenario and the second, an ocean monitoring [10] scenario and subsequently presented our results with regard to the better protocol for each of the scenarios.

Increasingly, military operations require wireless network connectivity for the flow of command and control information from the central command to the deployed field units. Since the military is a highly mobile entity, it requires networks that can be set up and configured in an unpremeditated fashion. Moreover, since security and mobility are critical factors to the military, DTNs provide all of these. So, DTN plays an important role for message transmission in military operations.

Similar is the reason when it comes to ocean monitoring, as to why we should implement Delay Tolerant Networks for Marine Surveillance Systems (MSS). These MSS are majorly the Ocean sensor networks (surface / underwater nodes) that are used for data collection and transmission. But, the cost of using satellite based networks is very high and not feasible after a certain extent. So, a vessel-DTN [10] is proposed which is highly cost effective.

We have studied different mobility models and tried to find out the optimum model for the each of the scenarios. The purpose of the study of different mobility model was to know about the available mobility models used in the ONE simulator as it affects the performance of DTN routing protocols significantly and the fact that every scenario demands a situation-specific mobility model.

After finding the most suitable mobility model for the two scenarios, we have studied different technologies [12] namely, ZigBee, Z-Wave, Bluetooth and Thread, to see whichtechnology performs better under the various metrics, delivery probability, number of relays and overhead ratio in military operations and ocean monitoring.

For military operations, our analysis suggest that Thread technology can be a suitable replacement for the existing Bluetooth technology. Both promises an equal Delivery Probability, but we found that the number of relays is 12.14% lesser in the case of Thread. In case of ocean monitoring, ZigBee can be used as an alternative to Bluetooth technology because of the increased transmission range that ZigBee offers.

This paper is structured as follows, Section 2 comprises of the related work in the domain of Movement Models in delay tolerant networks. Subsequently, we present our problem statement formally in section 3, which is followed by the pre-requisites to be able to present a solution to the problem statement in section 4 of this paper. Then we present our idea of implementation to conduct extensive analysis and move towards the results in section 4.1 and 4.2, and finally we conclude our work with section 5.

II. RELATED WORK

In the past considerable amount of research efforts have been invested on the mobility models [8]. Mobility models reflect the real mobility patterns of the nodes which helps in evaluating the performance of DTN protocols. The simplest traditional models which usually cover only selected mobility characteristics are the Random mobility models.

Following are the popular Random mobility models [2]:

1. Random walk (RW) Model: A simple mobility model that relays on random speeds in random directions.
2. Random Walkway Point (RWP) Model: A model that adds pause times when nodes assume new destinations and speeds.
3. Random Direction (RD) Mobility Model: A model that drives nodes up to the boundary of the simulation area before changing direction and speed.
4. Levy Walks (LW) Mobility Model: A model that derives travel lengths and pause times from a power law distribution.

Another type of mobility model is Map-Constrained Mobility Model in which random pattern is constrained within the map. In these models, map data is included using a subset of the Well-Known Text (WKT) format. Following are the popular Map-constrained mobility models [2]:

1. Map-Based Mobility Models (MBM): A model that moves nodes with random speed and direction following a map.
2. Shortest Path-Based Map Mobility Model (SPBMM): A model that is like MBM, but for all nodes it decides a certain destination first and then finds the shortest path to that destination.
3. Route-Based Map Mobility Model (RBM): A model that have pre-decided route for each node on the map.
4. Manhattan Mobility Model (MMM): A model that divides the map into a grid of horizontal and vertical lines to drive the nodes with pre-decided probability.

Many researches have been made on different wireless technologies. Wireless technology is often an integral part of military and oceanic monitoring scenarios. Military scenarios are narratives that describe situations within which the military may need to operate. Military personnel, including military network operators, use these technologies to transfer relevant information. Similar are the vessels, ships and on-shore sinks that are implemented as the DTN nodes in oceanic monitoring. The requirement of studying various protocol is to find a suitable alternative to the currently used Bluetooth technology [16], which has a limited connectivity in terms of the number of nodes and also the range of transmission. Following are the different wireless technologies:

1. Bluetooth:Bluetooth [20][23] is a wireless technology that uses short wavelength radio waves for data transmission over fixed and mobile devices. The range of Bluetooth devices is limited to about 10 meters (30 feet) only.
2. ZigBee: ZigBee [18][19] is a wireless technology used for remote control and sensor applications which is suitable for operation in harsh radio environments and in isolated locations. Zig-Bee consumes less energy and is used in low data rate application and secure networks. It is economical as well. It has a fixed data rate of 250 kbps and its range is up to 100 meters.
3. Z-wave: Z-wave [20][21] is an upcoming technology that is mostly used home automation application. It uses Radio Frequency for signaling and control. It offers a throughput of 100kps and its range is about 30 meters with the ability to hop up to four times between nodes.
4. Thread:Thread [17] technology connects a large number of devices with each other and also with the cloud server. It is based on two architectures, IPv6 and 6LoWPAN, offering a throughput of 250kbps and a theoretical range of 100 meters. The advantage that Thread has over the ZigBee technology is that Thread networking allows IPv6 addressing of nodes.
5. Wi-Fi: (Wireless Fidelity) is the technology that allows devices to connect to the internet over a

Wireless LAN via an access point. Low power Wi-Fi typically offers a bandwidth of 10Mbps and devices within an aerial distance of 70-200m^2.

TABLE I. TRANSMISSION RANGE AND SPEED FOR DIFFERENT TECHNOLOGIES

Technology	ZigBee	Z-Wave	Bluetooth	Thread	Low Power Wi-Fi
Transfer Speed	250 kbps	250 kbps	100 kbps	250 kbps	10 Mbps
Transfer Range	100 meter	30 meter	10 meter	100 meter	100 meter

III. PROBLEM STATEMENT

The Delay Tolerant Network (DTN) routing protocols have been designed for the environment where there is discontinuous path between source and destination at all points of time. But the problem when it comes to the applications such as military communication and oceanic monitoring is that the range of the existing technology being used is limited and also the number of nodes participating in the communication at a particular time is not flexible, so there is a need to find an alternative technologies that could replace Bluetooth and still be as good with the Delivery Probability and Overhead Ratio [11] incurred.

In this paper, we have focused on optimizing the range and speed of transmission between the nodes in the military and oceanic monitoring scenarios as it is of utmost importance for transmission of messages during emergency situations. For this purpose, first we have studied the different mobility models in the ONE simulator and based on our study, we have inferred the most suitable model. After finding the best mobility model, for the different wireless technologies namely Bluetooth, Wi-Fi, ZigBee, Z-Wave and Thread, we focus on simulating these parameters over the Prophet Protocol [7] in the ONE simulator.

IV. PERFORMANCE EVALUATION

First, we study the different technologies namely ZigBee, Bluetooth, Wi-Fi, Z-Wave and Thread technology. The protocols can be implemented on Opportunistic Networking Environment (ONE) [4] simulator. ONE allows for easy extensibility using Java and has been widely used for DTN and mobility research [2]. The performance of routing protocols is evaluated based on three metrics, namely Delivery Probability [11], Number of Relays [11] and Overhead Ratio [11].

Second, we study the mobility models and the scenario which will be suitable in military operations and ocean monitoring. We define the stationary nodes which will act as a destination nodes in these scenarios as well as the speed of the nodes in the scenarios. In the military scenario, we define the speed of the soldiers and in ocean monitoring, we define the speed of the vessels and the ships that act as nodes.

For military operations and ocean monitoring scenarios, we have used the transmission range and speed characteristics of ZigBee, Z-Wave, Bluetooth, Wi-Fi and Thread, and simulated the above-stated two scenarios in ONE Simulator. Then we compare these technologies in terms of Delivery Probability, Number of Relays and Overhead Ratio.

A. Implementation For Military Scenario

For military operations [1], there are different groups like soldiers, tanks, aircrafts and stationary nodes (stations) with different speeds and mobility model for each group. For soldiers, there are two groups, group1 and group2. The speeds range in 1-1.5m/s and mobility model used is Shortest Path Based- Mobility Model and RandomWalk respectively. Another group is Aircrafts, for which we have used a RandomWaypoint model and the speed is in the range of 56-110m/s. The tanks also use the RandomWaypoint mobility model and run with the speeds of 12-17m/s. For stationary nodes, we have used a RandomWalk mobility model and since these are acting as stationary nodes so the speed of this group is 0 m/s.

1) Result And Analysis

Increasing transmission range increases the delivery probability, as more nodes come into the range of the destination node. From figure 1, Wi-Fi can be considered as an alternative to Bluetooth technology as the Delivery Probability is very high.

Figure 2, shows the impact of transmission range on number of relays. It can be seen that number of relays for Wi-Fi is very high. Therefore, power consumption [14] for Wi-Fi will also be high as power consumption is directly proportional to Number of Relays. So, Wi-Fi cannot be used as an alternative to Bluetooth technology. Further, we analyze that the number of relays for Thread technology is 3.75% less as compared to ZigBee and 12.14% less as compared to Bluetooth technology.

From figure 3, we can see that the overhead ratio for Thread is 2.52% more than ZigBee and 3.14% more than Bluetooth technology.

ZigBee and Thread can be used as an alternative to the Bluetooth technology as the delivery probability is same for both the ZigBee and Thread technology. The high Overhead Ratio values can be compensated when other parameters are taken into consideration. Since, we have to find a suitable technology to be used in military operations, Thread can be best used as an alternative to Bluetooth technology for transmission of messages in military operations.

TABLE II. SIMULATION PARAMETERS FOR MILITARY SCENARIO

Parameter	Soldiers (Group 1)	Soldiers (Group 2)	Tanks (Group 3)	Aircraft (Group 4)	Stations (Group 5)
Number of Hosts	100	100	100	15	10
Speed (m/s)	1-1.5	1-1.5	12-17	56-110	0-0
Wait Time (sec)	0-120	0-120	0-120	10-30	10-30
Buffer Size	50M	50M	50M	500M	50M
Packet TTL(sec)	300	300	300	300	300
Simulation Time(sec)	4320.0	4320.0	4320.0	4320.0	4320.0
Movement	SPMBM	Random Walk	Random WayPoint	SPMBM	Random Walk

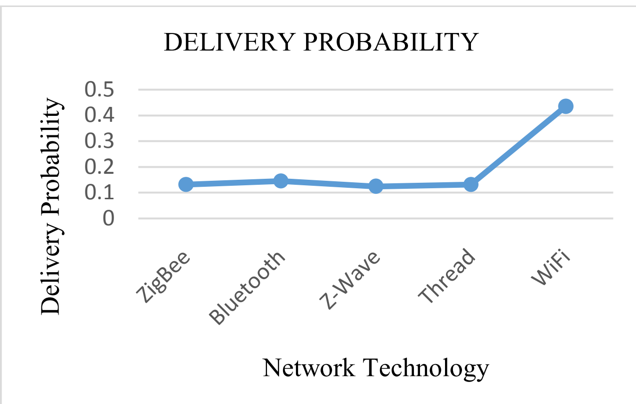

Fig. 1. Impact of transmission range andspeed on Delivery Probability

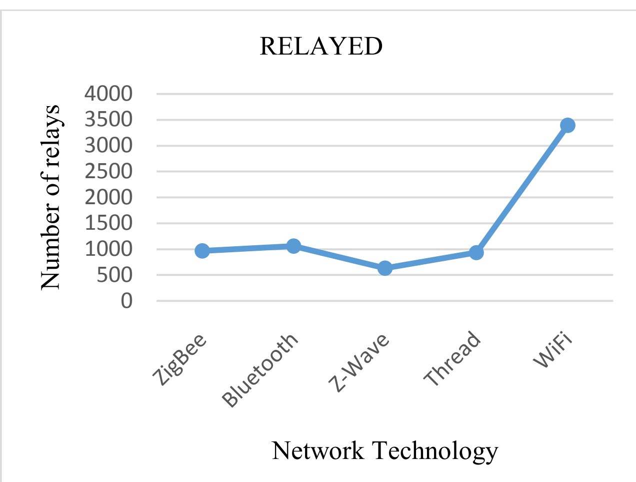

Fig. 2. Impact of transmission range andspeed on Number of Relays

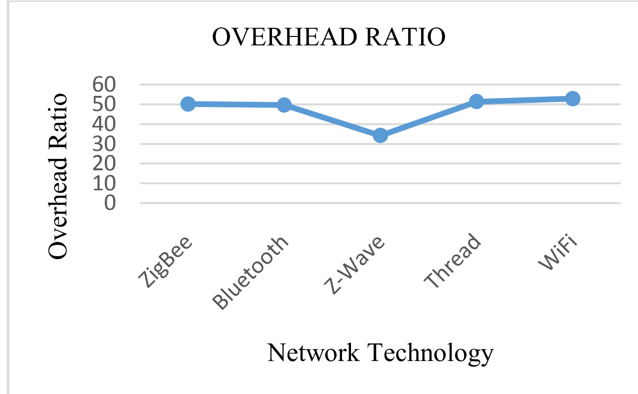

Fig. 3. Impact of transmission range and speed on Overhead Ratio

B. *Implementation For Ocean Monitoring*

For ocean monitoring [10], there are three groups, stations (which are acting as a stationary nodes), sensors and vessels, and each group is having different speeds and mobility model. For stationary nodes, the mobility model used is Random Walk. For sensors, the mobility model used is RandomWaypoint and the speed of this group is 2-5m/s. for vessels, we have used RandomWaypoint mobility model and the speed of this group is 1-1.5m/s.

1) *Result And Analysis*

Increasing the transmission range increases the Delivery Probability as more nodes come into the range and therefore more packets are transferred to the destination node. From figure 4, the Delivery Probability of Wi-Fi is greater than that of all the other technologies. So, Wi-Fi can be considered as an alternative to Bluetooth technology.

From figure 5, it can be seen that the number of relays is more in Wi-Fi as compared to other technologies. Hence, it is not a suitable alternative for Bluetooth. Rather, the Number of Relays is less for ZigBee and Bluetooth. Thus, ZigBee can be used in ocean monitoring, since number of relays is 71.42% less than Thread and 68% less than Z-Wave technology.

Further from figure 6, we conclude that the Overhead Ratio for ZigBee is 63.98% less than Thread and 59.07% less than Z-Wave technology.

Delivery Probability for Z-Wave and Thread is comparable and that of ZigBee and Bluetooth is same and is 33.33% less than Z-Wave and Thread. Therefore, we can say that for ocean monitoring, the best alternative to Bluetooth technology is ZigBee technology in terms of Number of Relays and Overhead Ratio but the Delivery Probability can be compensated for, when we consider the other parameters.

TABLE III. SIMULATION PARAMETERS FOR OCEAN SCENARIO

Parameter	Station (Group 1)	Sensors (Group 2)	Vessel (Group 3)
Number of Hosts	100	100	100
Speed (m/s)	0-0.5	2-5	1-1.5
Wait Time (sec)	0-120	0-120	0-120
Buffer Size	500M	500M	500M
Packet TTL(sec)	300	300	300
Simulation Time(sec)	4320.0	4320.0	4320.0
Movement	RandomWalk	Random Waypoint	RandomWalk

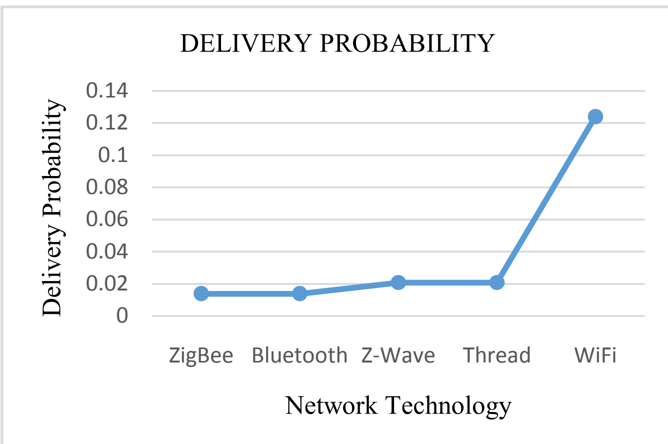

Fig. 4. Impact of transmission range and speed on Delivery Probability

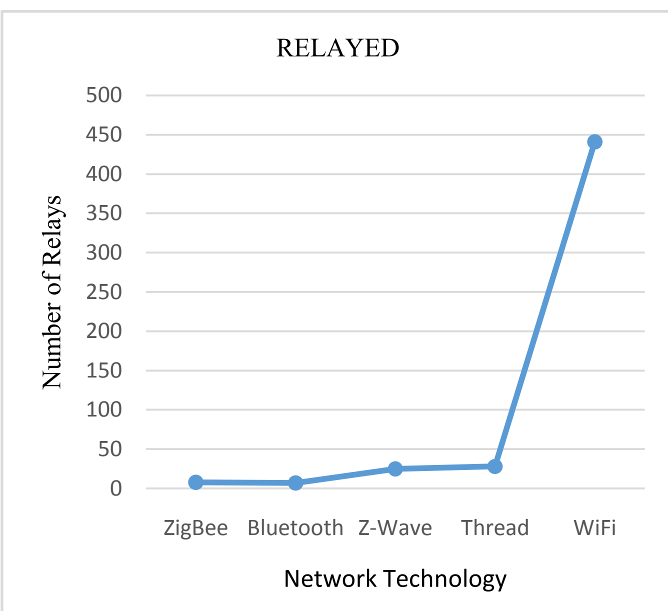

Fig. 5. Impact of transmission range and speed on Number of Relays

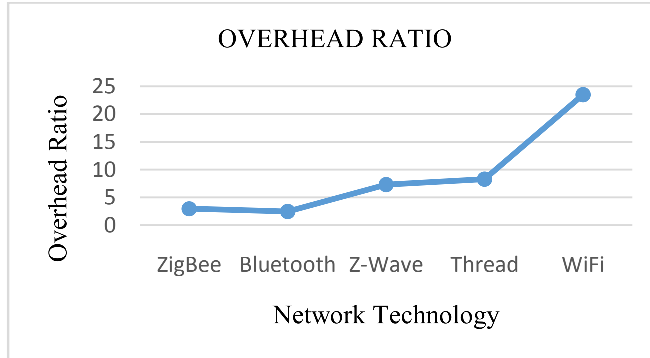

Fig. 6. Impact of transmission range and speed on Overhead Ratio

V. CONCLUSION

Towards the aim of finding a suitable substitute for existing Bluetooth technology that can offer higher transmission speed and greater range in area specific application like military scenario and oceanic monitoring where these parameters are of critical importance, this paper investigates various existing technologies like ZigBee, Z-Wave, Thread, Wi-Fi.

So far, we have studied the different technologies to find the most suitable technology that can replace Bluetooth technology in military operations and ocean monitoring which can optimize the range and speed parameters of DTN nodes. We have taken the parameters of each of the technologies and the simulations have been performed in ONE Simulator. Subsequently, the results have been compiled after comparison with Bluetooth technology.

For military operations, we have come to the conclusion that Thread technology can replace Bluetooth technology. Thread technology results in the same Delivery Probability as that of Bluetooth technology and the number of relays is 12.14% less and Overhead Ratio is 3.14% more than Bluetooth technology. Further, Thread technology uses IPv6, which makes the nodes addressable and enhances the security, which is one of the most critical parameters in military operations.

For ocean monitoring, ZigBee technology can be the most suitable substitute for the existing Bluetooth technology. It shows the same Delivery Probability as Bluetooth technology but has a higher overhead ratio. But since we need to have a better range of transmission of packets, we conclude that ZigBee can be a better option as compared to Bluetooth and all the other technologies.

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