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Imapct of Node Speed Variation on the Performance of a Manet Routing Protocol under OFDM (IEEE 802.11A) and DSSS (IEEE 802.11b)

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Abstract

A mobile ad-hoc network (MANET) is a decentralised network made up of nodes that move in the pattern of the mobility model specified in the network. Because MANET does not have a centralised system, each node can serve as a router, and with nodes in a random movement at a high speed the quality of signal transmission in the network can be affected. Routing protocols form an integral part of any network whether ad hoc or infrastructure based. In MANET, there are two main categories of routing protocols namely: reactive and proactive protocols. In this paper performance of a proactive protocol (OLSR) has been investigated under two different physical layer modes: Direct Spread Sequence Spectrum (DSSS) and Orthogonal Frequency Division Multiplexing (OFDM) to determine which medium provides more efficiency in data transmission under a highly unpredictable mobility model.

Keywords - *DSSS. Flow-Monitor. MANET. Mean Delay, Mean Jitter, NS-3 OFDM. OLSR, Packet Loss, PDR.*

I. INTRODUCTION

There are two classes of wireless network: infrastructure dependant and infrastructure independent that is mobile ad hoc networks. The former requires an access point, which links the wired and wireless components of the network, these are the types of networks we have in our schools, homes and offices. The infrastructure independent networks is ad hoc network, this network is dynamic in nature and therefore does not require a fixed infrastructure, in this case node connect to each other directly without the depending on the any device to serve as a bridge connect it and the another wired network. Such is the type of network that is used by military, fire fighters, in V2V or ship-to-ship communication, and other events that unpredictable (e.g hurricane devastation, tsunami, earthquake terror attack) [1, 2].

A wireless ad hoc network consists of two or more nodes capable of exchanging data packets with each other without the facilitation of a centralised system.

The nature of wireless ad hoc network is such that each node performs a dual function of being a host as well as a router; in this type of network topology changes as nodes leave or join the network and as the node speed increases. Therefore, there is a need for routing a protocol an a robust medium access control layer mechanism that can ensure transmission and routing of packets between a source and a sink in an efficient way [1].

There are two of such medium access schemes that we seek to subject to test in this paper, with a view to finding the robustness of each under transmission limiting factors that might be introduced by node speed variation. Increase in power reduces the impact of mobility, what we seek to achieve here, is to keep the power constant while we increase the node speed, and see how that will affect the performance of OLSR under OFDM and DSSS using some selected performance metrics [1].

II. BASIC OF ORTHORGONAL FREQUENCYDIVISION MULTIPLEXING (OFDM)

OFDM is both modulation scheme as well as a multiplexing scheme, it is a form of multicarrier scheme that splits a high data rate stream into a number of smaller low data rate streams or subcarriers, modulating each carrier independently hence, reducing intersymbol interference (ISI) by stretching the symbol durations. In OFDM, the subcarriers are orthogonal to each other; that is 90^0 apart. The separation results in achieving high spectral efficiency thus, utilising virtually the entire frequency band [3].

Figure 1 below shows a schematic diagram of an OFDM transmitter and receiver. To generate OFDM symbols, a high data rate stream of bits is undergoes conversion from serial-to-parallel, these parallel bits are them modulated onto N parallel subcarriers for transmission. This technique increase the symbol duration by a factor of N, making it considerably bigger than the channel delay spread. The next step is the generation and insertion of the cyclic prefix (CP), which are added at the start of each OFDM symbol. This addition is done when the output of the serial-to-parallel go through IFFT. The additions of the CP helps in removing any remaining inter symbol interference that might have been induced by multipath propagation. Apart from the function of removing ISI, CP also helps in recovering the OFDM symbols [4].

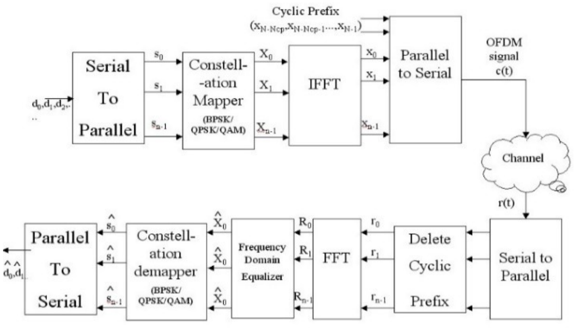

Figure 1. OFDM Transmitter and Receiver [5]

When the OFDM signals reach the receiver, reverse operations are performed on the signals to recover the previously modulation information bits [4].

OFDM subcarriers are modulated using one of the four modulation schemes supported in 802.11a physical layer, which are: BPSK, QPSK, 16-QAM and 64-QAM. The less advanced frequency division multiplexing addresses the problem of channel interference by using guard band to separate channels. In OFDM, however, the orthogonality of the subcarriers prevents interference between adjacent carriers. The 802.11a physical layer operates at a higher frequency than the 802.11b [6]

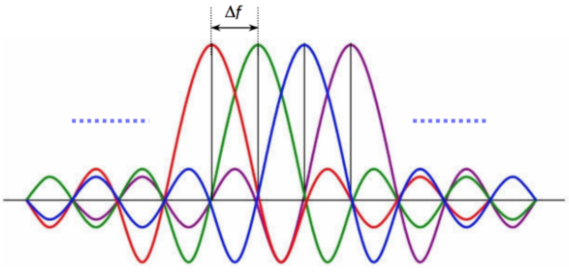

Figure 2. : OFDM Subcarriers Spacing [7]

Despite its numerous advantages, which include high spectral efficiency, robustness against channel impairments etc., OFDM performance can be affected the frequency offset and peak to average power ratio (PAPR) [6].

The IEEE 802.11a PHY uses orthogonal frequency division multiplexing as the underline modulation scheme. OFDM is widely adopted by the physical layers of modern day wireless technologies, such as LTE, and WIMAX due to its advantage. There is a sum of 52 sub-carriers in 802.11a with 48 of them as data subcarriers and the rest as the pilot subcarriers. In the frame physical layer convergence procedure (PPDU) of 802.11a sublayer, convolutional codes are used to encode the bits. 802.11a supports 6 different data rates; between 6 and 54 Mbits/s within a frequency band of 5GHz [6, 8].

III. DIRECT SEQUENCE SPREAD SPECTRUM (DSSS) (802.11a)

There are two major subsets of spread spectrum, namely; the Direct Sequence Spread Spectrum (DSSS) and Frequency Hopping Spread Spectrum (FHSS). DSSS was invented by the military to mitigate signal jamming and spying. The basic method used in this technique is conversion of the digital signal into a more noise-like sequence of bits. These generated high speed digital sequence are then modulated on carrier frequency by employing any of the modulation schemes that can be used in 802.11a. However, the most widely used modulation scheme in 802.11b is the differential shift keying [9].

The diagram below shows how DSSS operates; the information sequence after passing through the channel encoder are modulated with some carefully generated random sequence of bits, called Barker code [10]

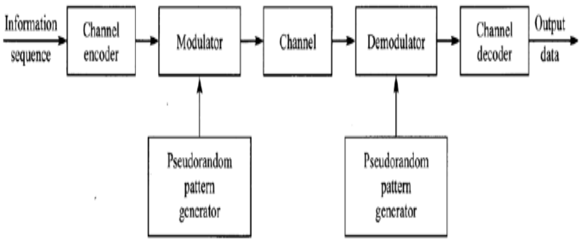

Figure 3. A diagram of DSSS Digital Communication System [11]

Combining the information bits with these 11-bits sequence makes it more robust against jamming and interference. Another added advantage of using these codes is, in case of an event that results in the loss of one or two bits of the code, there are techniques that can statistically recover the lost bits, thus no retransmission is needed [10].

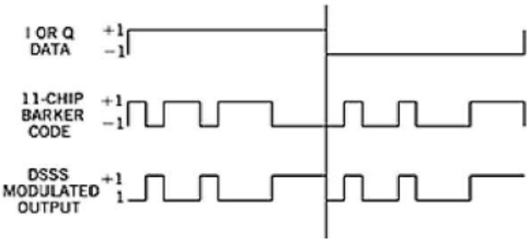

Figure 4. Diagram Showing How Original Information Bits are Combined with Chipping Code [10]

In DSSS, the 2.4GHz band is divided into 14, 22 MHz channels, out of which 11 contiguous channels partly overlap while the remaining 3 have no overlap[10].

Another high-rate modulation scheme that is used in 802.11b is the *complementary code keying* (CCK). This scheme uses 64-bit instead of the 11-bits as in the case Barker code. With 64 unique bits and QPSK as modulation, CCK can transmit data at two different high-rates, each almost twice the corresponding rates that can be achieved by the Barker code. To recover the original transmitter information bits, the DSSS receiver uses another set of pseudorandom sequence used to remove the codes (Barker/CCK codes) that were used at the transmitter [10].

IV. CLASSIFICATION Ad HOC ROUTING PROTOCOLS

There are moderately a lot of ad hoc protocols developed for efficient, speedy, and dependable routing, for use in a network with high degree of variability in its topology. This set of protocols must be able to handle the constraints of an unpredictable structure, which include excessive power consumption, low throughput and significant error probability. The protocols are grouped into three categories: proactive/table-driven protocols, reactive protocols/on-demand and another category of routing protocols known as hybrid. The categorisation distinguishes the routing protocols on the basis of their procedure, hop count, link state and source routing in a path-selection procedure. In the category identified with hop count, a node maintains its next-neighbour information in the routing table, mapped to the destination. Link state routing protocols keep a complete routing table of the entire network, the table is put together through determining the shortest path to destination. For source routing system, headers are used by packets to carry the routing information [1]

A. The Proactive Manet Routing Protocols

This class of ad hoc routing protocols are also referred to as table driven routing protocols. Unlike reactive protocols, the proactive protocols maintain routes to all the nodes in the entire topology. Routing table is updated whenever a node enters or leaves the network or when the topology structure changes. The information on the change to the network number of nodes or topology is sent periodically using hello packets. This mechanism makes takes away the complexity and the delay in finding the route when a node has some packets to send. However, this mechanism is characterised by higher routing overhead compared to the previous mechanism because of the volume of routing information that is maintained, a portion of which might not be useful, although obsolete routes are replaced with newly discovered ones [1, 12, 13].

B. The Optimised Link State Routing Protocol

OLSR is a table driven routing protocol, this protocol uses three techniques for routing packets across the network: (i) neighbour sensing by sending HELLO packets at regular intervals, (ii) regulated packet flooding across the network by selecting some nodes as MPRs based on number of nodes that a sources is connected to, (iii) selecting path by employing shortest path first algorithm (SPF). In OLSR, nodes select their one hope neighbours as their multipoint relays (MPRs). The idea is to make the routing protocol more efficient by reducing the size of the control messages that are exchanged by the nodes and the number of the nodes that broadcast such messages. Each node uses hello message to broadcast list of its one hop neighbours periodically out of the set of nodes in the hello messages, every node selects a subsection of one hop neighbours that has connection to its entire two hop neighbours as its MPRs. When packets are sent by a node, every other node has the privilege of reading and processing the packets. However, only the nodes that are in its set of MPRs can retransmit the packets [12, 14].
Consequently, with the use of their topology information, nodes separately find the optimum route to known destination(s) and store the route in their respective routine tables[14].

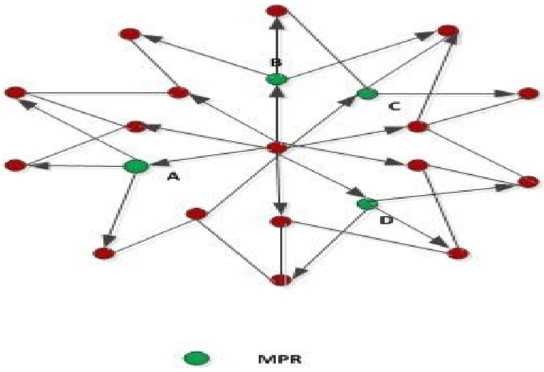

Figure 3: MPRs

V. RANDOM WAY MOBILITY MODEL

Movement of nodes affect the performance of ad-hoc routing protocols. Mobile nodes move by following the pattern of adopted mobility model. The mobility model determines the rate at which nodes location and acceleration change with time [1].

In Random Waypoint mobility model, nodes are randomly assigned positions in a specified area. These nodes then move to the designated positions in a linear form, each with constant arbitrary speed. The movement stops for an interval referred to as the pause time before the subsequent movement. The pause interval is determined by model initialisation and its speed is evenly distributed [LSpeed, HSpeed] [1, 15].

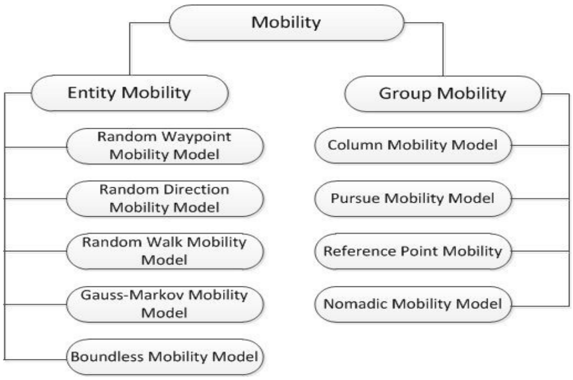

Figure 4: An example of Some Mobility Models[15]

The pattern that nodes follow in Random Waypoint introduces changes in the topology. Both velocity and pause time have influence on the performance of ad hoc routing protocols, because low node speed and high pause time result in relative stability in the network topology, whereas high node speed and low pause time make the network topology very unstable [15].

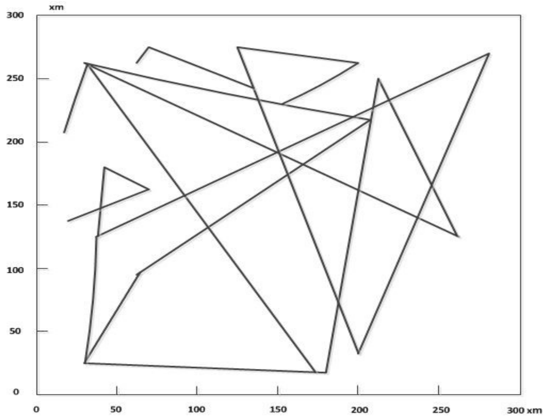

Figure 5: Nodes Travelling Pattern in RMWPM model

The figure above illustrates the movement pattern of nodes in Random Waypoint mobility model in a demarcated area of 300x300 m^2. Each node moves linearly in a given direction and only turns upon reaching the boundary of the area [15].

VI. THE SIMULATION SET-UP AND SCENARIO

The simulation in this paper is based NS-3 simulator, which is a discrete event simulator used mainly by researchers and in academia for teaching and research

A. Scenario

A scenario of 20 mobile ad hoc nodes in an open square field of 300m X 300m in dimension operating Random Waypoint mobility model and Friis propagation lossmodel was simulated to measure the effect of node speed variation on performance of OLSR under Orthogonal Frequency Division Multiplexing (OFDM) and Direct Sequence Spread Spectrum (DSSS). The pause time was kept constant at 0 m/s while the node speed was varied, this was to measure the efficiency of OLSR protocol under these selected schemes. The simulation reflected a real life emergency situation where nodes have to move randomly and at a high speed. The scenario consists of 5 source/sinks that were exchanging a total of 20 UPD packets per second. Each UDP packet is 64 bytes in size. The transmission power was kept as 2.5150047 dBm to enable the assessment of the effect of mobility on the performance of OLSR. The simulation ran for the duration 200 seconds out of which 10 seconds were used as start-up time before the nodes begin exchanging the application data. This scenario can apply to police casing a suspect in a park or a case of rangers chasing a poacher in a game reserve. Another real life application of this scenario is a rescue operation in a flood battered area where rescuers are constantly moving while trying to save a person or a group of people from drowning.

Table 1: Simulation Parameters Values

Parameter	**Value**
Simulation Time	200 seconds
Pause Time	0 seconds
Number of Nodes	20
Number of Sinks	5
Speed	2,5,10,15,20 m/s
Transmission Power	2.51500457 dBm
Mobility Model	Random Waypoint Mobility Model
Routing Protocols	OLSR
Area	300x300 m^2
Application	UPD
Physical Layer Mode	OFDM

B. Simulation Analysis

The performance metrics based on which the performance of the routing protocols were analysed and compared.

- **Throughput**: This is the measure of the rate at which the network transfers data to the destination over a given period of time[16]

$$\text{Throughput} = \frac{RecivedBytes * 8}{Simulation\ time * 1024} \qquad [17]$$

- **PDR**: This is thefractionin percentage of the data packetsthat reached the targetnode and the number of packets transmitted by the sending nodes [16].

$$\text{PDR}=\frac{No.\ of\ packets\ received}{No.of\ packets\ sent}\ \text{X}\ 100[17]$$

- Average jitter: Jitter is simply the variation in packets arrival time at the destination. The lower the jitter, the higher the performance of a routing protocol. Jitter is introduced by a number of factors, some of which are: network congestion, topology change, and impairments [16].

$$\text{Average jitter}=\frac{jitterSum}{rxPackets-1}\quad[17]$$

- Mean delay: This is the mean time taken by single data packet to reach the destination. It includes the delay introduces during the process of route discovery, as well as the queuing delay experienced by packets during transmission [16].

$$\text{Mean delay}=\frac{delaySum}{rxPackets-1}\quad[17]$$

- Packet Lost

This is sum total of data packets that were dropped during transmission [16].

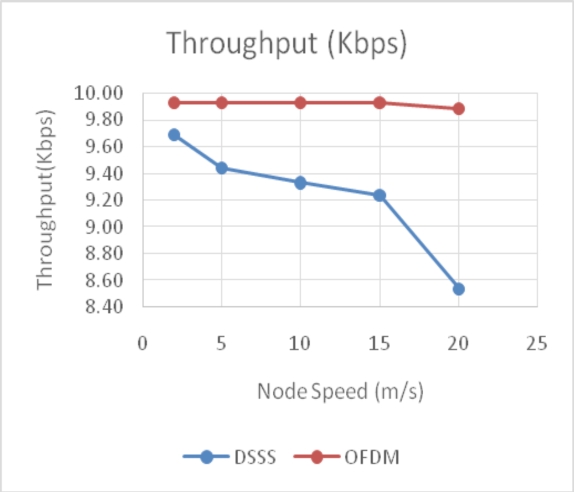

Figure 5: Throughput of OLSR in 802.11a and b

Throughput: Figure 5 above shows the throughput performance if OFDM and DSSS and a range of node speed. It can be observed that the increase in node speed had minimal impact on the throughput of 802.11a compared to 802.11b. OFDM maintained a steady throughput transmitting 9.93 Kbps out of 10kbps total data rate at which the five sinks/sources where transmitting application data from when the nodes were travelling at the speed of 2m/s up to when 15m/s. It then reduced to 9.89 Kbps when the node speed reaches 20m/s. This shows that 802.11a (OFDM) technology is clearly very robust and resistant to impairments and other factors that can affect data transmission as a result of the speed of nodes mobility. For 802.11b (DSSS), the increase in node speed resulted in decrease in throughput. Each time the speed increases the throughput decreased. Considering the number of channels and the modulation schemes in each standard, it can be concluded that 802.11a (OFDM) is more robust compared to 802.11b (DSSS).

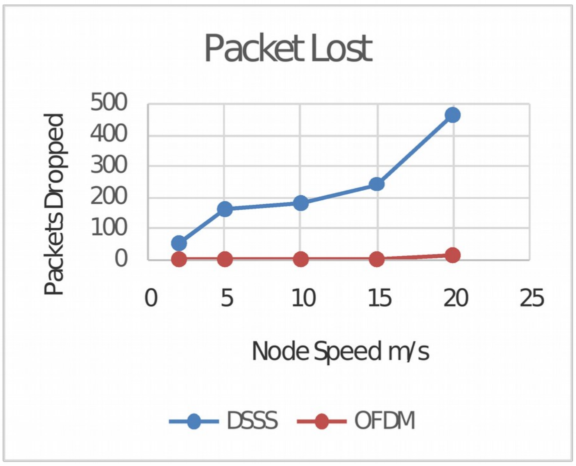

Figure 6: Graph of Packets Lost Against Node Speed (m/s)

Packet Loss: The number of packet lost was obtained by taking the sum of packets that were dropped during the process of transmission, under a give node speed. The comparison demonstrates that the amount of packets dropped under 802.11b (DSSS) was directly proportional to the node speed. As the mobility increases, DSSS suffered more and more packets lost. 802.11a (OFDM) suffered a very minimal packet loss when the node speed reached 20m/s. Therefore, we can deduce that DSSS is less resistant by far to effects of high mobility.

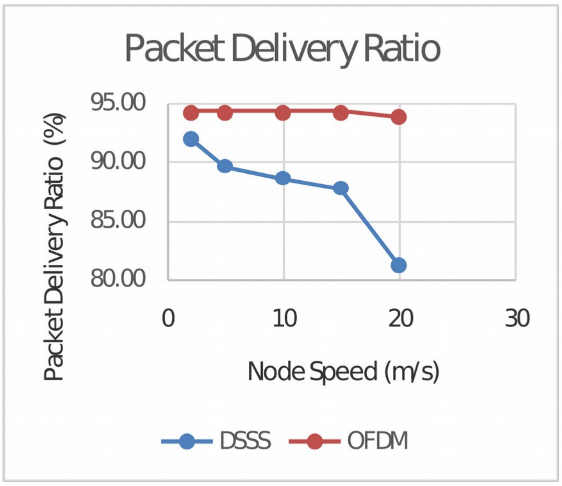

Figure 7: Packet Delivery Ratio (%) vs Node Speed (m/s)

PDR: Fig. 7 shows the variation of PDR as the mobility increases. Again we can observe that OFDM which previously showed better performance in throughput, still has better packet delivery ratio. Once again, DSSS performs less than the OFDM in delivering packets to the destination.

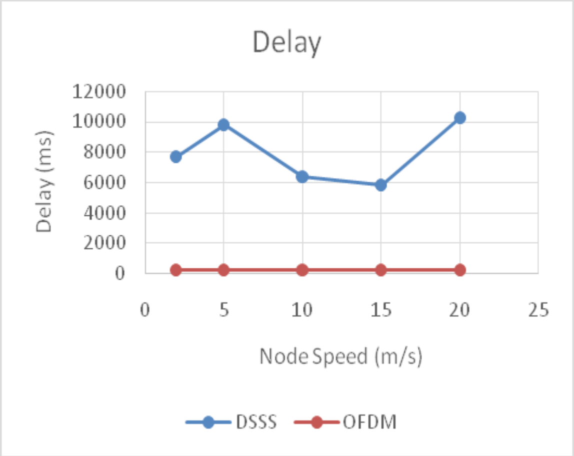

Figure 8: Mean Delay (ms) vs Node speed (m/s)

Mean Delay: Fig. 8 shows average delay recorded at during transmission at different speed levels. Since we have seen that OFDM has higher throughput, PDR and lower packet loss, it is expected that it should experience low delay.

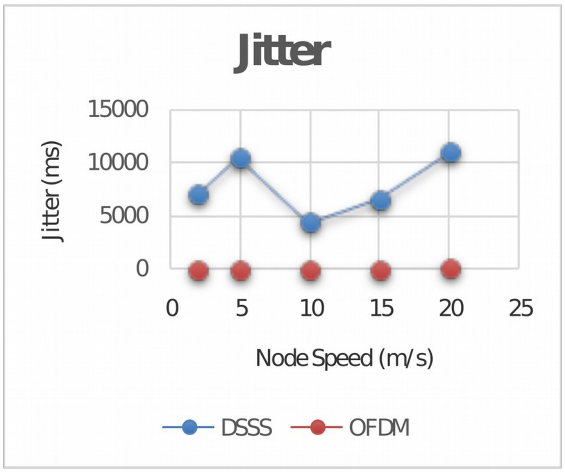

Figure 9: Average Jitter vs Node speed

Average Jitter: this is the variation in packets arrival time to the destination. Fig. 9 shows the average jitter in ms, per given node speed. The jitter of 802.11b is in thousands of milliseconds while that of 802.11a is in hundreds of milliseconds. Thus, we can conclude that DSSS suffers more jitter that OFDM.

VII.CONCLUSION

Conclusively, we have seen how OLSR performed under these two technologies. It is clear that 802.11a (OFDM) performed better than 802.11b (DSSS), node mobility affect the network topology in many ways; one of which is by causing link failure, and as a link fails a routing protocol will try to re-establish another link in order to maintain connectivity in the network. Because DSSS has fewer channel compared to OFDM, DSSS suffers more from the effect of link failure than OFDM when both are transmitting at the same data rate.

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