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Handover Enhancement for 6LoWPAN mobile sensor networks

Ali Adnan AL-KHAZRAJI, Yasir W. Abduljaleel

Computer Engineering Dept., Iraqia University, Baghdad, Iraq

Civil Engineering Dept., Iraqia University, Baghdad, Iraq

engaliadnan00@gmail.com

yasir.wisam@aliraqia.edu.tr

ORCID:0009-0008-6402-6484

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Abstract— One of the major challenges in Wireless Sensor Networks is that certain applications use a variety of proprietary techniques that are harder to integrate with the internet, including the capacity to offer internet services for mobile devices. As a result, IPv6-based Low Power Wireless Personal Area Networks was developed to overcome these limitations. Its nodes have been made highly flexible, and scientists have increased their efficiency by allowing them to move and act as mobility nodes. This study provides a new paradigm for improving 6LoWPAN handover to overcome the problems mentioned above, based on both Layer 2 (L2) as well as Layer 3 (L3) in order to enhance handover effectiveness. The quantity of thresholds approached mostly by coverage area is what makes this study unique. In handover decisions, two thresholds were used to determine the node's mobility using RSSI and LQI; this notion has not been explored in earlier works that rely just on one threshold. The first serves as mobility detector, whereas the second serves as disconnect-reconnect element. A timer-based signal distribution approach was introduced. The method may effectively minimize handover duration, packet loss, and handover prices using these methods, which is the goal of this study. According to the results obtained, the handover delay is 43.84% far less than previous work, handover costs are decreased by 24.93%, and packet loss is lowered by 43.76%.

Keywords: WSN, Received Signal Strength Indicator, Personal Area Network, Handover.

I. INTRODUCTION

IPv6-based Low Power Wireless Personal Area Networks (6LoWPAN) are built of nodes with low power, restricted memory, and restricted resources. The Wireless Sensor Network (WSN), inside which sensor nodes could sense specific physical properties, is the most prevalent and prominent example. They should enable the mobility of a 6LoWPAN protocol to allow it to adopt an extra application in order to optimise it. The widespread availability of communications systems such as cellphones, laptops, and other similar devices has raised the demand for the world wide web to support these devices. The 6LoWPAN standard is more important since it enables nodes to self-organize, identify, configure, and recover with no need for human intervention [1-3]. Scientists previously attempted to exploit IPv6 connectivity in WSN to allow as well as furnish a major benefit to WSN [4]. Furthermore, IPv6-enabled devices may interface with another IPv6-enabled devices with no need for interpretations [5]. However, one of the major drawbacks of WSN that's based on IEEE 802.15.4, is that the frame size is restricted to 127 bytes [4]. The IETF proposed IPv6 on Power Wireless Personal Area Network to remedy this. Furthermore, the focus is either now or in the upcoming on IPv6, as many gadgets will demand internet connectivity. Most devices presently have the capacity to move and modify their places. The mobility nodes must be supported by the 6LoWPAN WSN for this. Latency handover delay, changeover cost, packet drop, and energy usage are the primary issues in the mobility system [6-8]. As an outcome, researchers have been tasked with developing a novel methodology or optimising a current one in order to attain the best possible outcomes for this variable. Several of techniques utilized to optimise 6LoWPAN mobility handover are subsequently resulted in a strategy to minimise those parameters based on position prediction, specified protocols including like PMIPv6 & MIPv6, as well as Layer 2 & Layer 3, or even both. Channel screening and network authorization are handled by Layer 2, whereas movement node recognition and registration are handled by Layer 3. Despite the fact that L2 and L3 collaborate, the latter starts and ends after the L2 handover [9]. This study provides a novel technique that enables the mobility strategy in attempt to get good performance in regards of handover delay, costs, and packet losses. Our technique can minimize handover latencies, packet drop, and handover expenses, according to the outcomes.
The following portion will go over the work that is connected to 6LoWPAN mobility as well as what the key answer is for everyone. The third half of this article will describe and present the methods. Our architecture will be presented in Section Four. The primary distinction among both intra-PAN and inter-PAN would be explained in Section 5. The mathematical method and also the simulation design will be presented in Section Six. Ultimately, the outcome and conclusion can be found.

III. OUR SOLUTION

Implementing mobility in the 6LoWPAN protocol allows it to accommodate an extra application [10]. The Internet Engineering Task Force (IETF) is, therefore, familiar with Low Power Wireless Personal Area Network standard for internet connection, which is dependent on IPv6.

There are two types of researchers working in this field. The earliest attempts to resolve intra-network handover concerns where the winning solution could not sustain the inter-network. This is due to the fact that intra-mobility seems to have only one gateway as well as borders router, as well as a single Personal Area Network (PAN). The inter-network, but at other hand, has two PANs or gateways, which we must consider. Other researches focus solely on inter-PAN optimization [11-14]. Others utilise location prediction, while others use alternative methods to boost the effectiveness of either L2 or L3 or both.

To estimate the distance and determine if the node is migrating, the methodology uses RSSI and LQI.

In addition, the Angle of Arrival (AoA) is used in this study to establish the orientation of the Mobility Node (MN) and the MN whereby the FFD will interact.

Furthermore, unlike prior works that relied on a single threshold, there have been two threshold values to select between connection and disconnection decisions. If the node crosses this value, it will detach from the first base station as well as searching for alternative base station.

The threshold values with each node are shown in Figure 1.

The approach relies on coordinating nodes to interchange, transmit, and received packets with MAGs in this study. The mobility nodes do not interact only with MAGs as a result of this. The packets can be delivered to the FFDs by the MN, and the FFDs can then continue their job and distribute the packets to the MAGs. As a consequence, because each broadcast or received signal expends energy, signalling expenses and energy usage can be decreased.

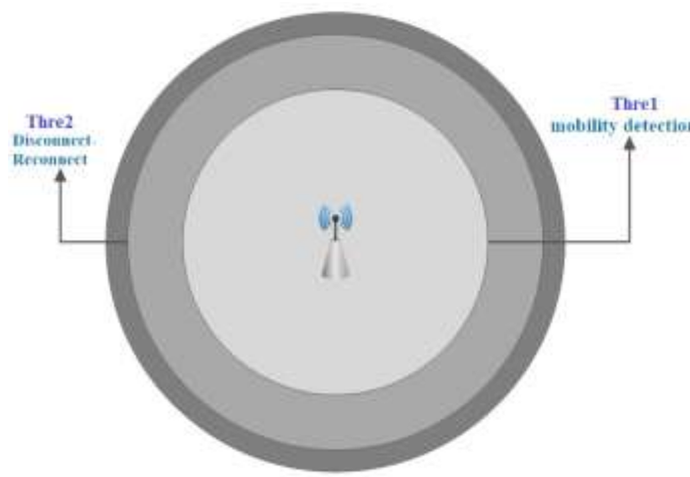

Fig.1: Node range

IV. ARCHITECTURE

The suggested improvement entails two PANs, each with its own subnet PAN and peculiar address. Single Media Access Gateway (MAG) serves as manager for each PAN and instantly connect to GW. There seem to be two types of nodes inside each PAN. In 6LoWPAN, IEEE 802.15.4 proposes two sorts of nodes, including one with a distinct role. A Full-Function Device (FFD) is the very first node, and Reduced-Function Device (RFD) seems to be second (RFD). Using forwarding and routing functionalities, the FFD nodes can interface with the RFD as well as the Media Access Gateway (MAG). They are also capable of making decisions and detecting travelling nodes. The FFD is permanent node that serves as coordinator for MN, MAG, and GW. The RFD is indeed a sensor node that can travel amongst or within PANs and modify its position. To avoid signaling prices and energy usage, the RFD nodes can connect with the MAGs using FFD. The Expanded LoWPANs [15] and the benchmark utilised [9] have the same main structure as shown in Figure 1.

The Link Quality Indicator (LQI), Received Signal Strength Indicator (RSSI), as well as Arrival of Angle (AOA) are the three types of parameters that the FFDs use to conduct the majority of the functions (AoA). The RSSI is utilized to calculate the distance amongst each MN and FFD, but because this isn't enough to get a precise results, the RSSI is supplemented by LQI to get a more correct distance. The MN orientation is obtained using AoA, in which the FFD is aware of the newer FFD, and MN connects to it and sends the message to MAG.

This study is based on Expanded LoWPAN framework, which consists of two subnet networks, within every Media Access Gateway (MAG), all of that are integrated in a single GW. The intra-mobility (micro) and inter-mobility (macro) mobility strategies in this research are separated into two categories.

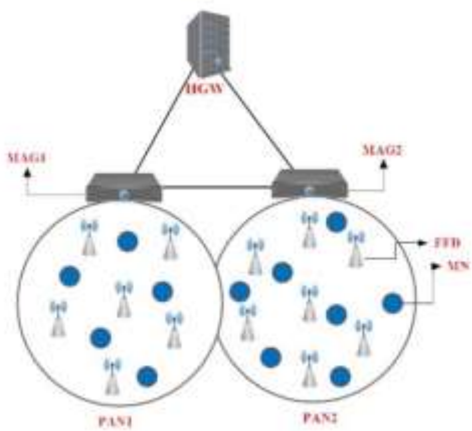

Fig. 2: Network.

The sections that follow describe both the aspects of this investigation and the signalling distribution for every one of them.

V. Handover Latency (Mobility Node MN)

1- Micro Handover or Intra-PAN Mobility

There seems to be a sole PAN in this design, which includes one RFD (MN), FFD, as well as MAG. In almost same PAN, the mobile node traverses through one FFD to the next. The intra-mobility feature is depicted in Figure 2. Whenever the sensor node (RFD or MN) moves, MN disconnects from former or current FFD (PFFD) and connects with fresh one. Because when MN reaches the threshold 1 (thre1), the FFD senses movement and uses the RSSI and LQI to compute distances and the AoA to estimate direction to start the handover. Whenever the PFFD reaches the second level of threshold, it transmits a handover (HO) event to MAG, which modifies the MN routing from the PFFD to just the NFFD (thre2). The timing in the PFFD is also initiated around the same moment. The timer's goal is to remove MN registrations from PFFD table. The nodes may not require any acknowledgement in this circumstance, resulting in a reduced signalling distribution. The MN would then associate with the NFFD, as well as the MAG will modify the packet's route. The signalling distribution in intra-mobility is depicted in Figure 3.

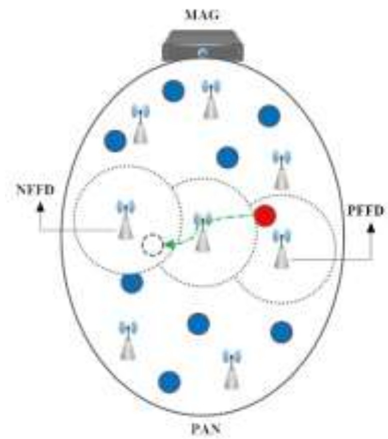

Fig.3: intra-mobility

Since there's no communication amongst the MAG and HGW, intra-mobility is straightforward. As an outcome, handover delay, signalling cost, and packet drop are lower than in part two (inter-mobility).

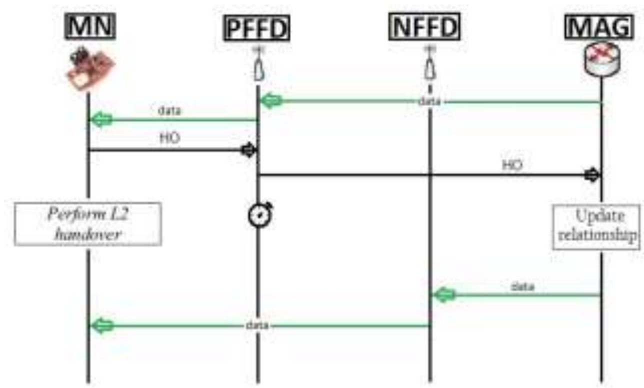

Fig 4: signaling distribution in "intra-mobility"

2- Macro Handover or Inter-PAN Mobility

The inter-mobility consists of two PANs, each with one MAG (referred as Edge Router). Both MAGs interact to HGW and connect with it effectively. The MN switches through one PAN to next. Inter-mobility can be divided into two categories. The first one is is now in the ideal situation, because when MN goes through one PAN to the other, as well as the second one is in the load traffic scenario, whenever the MN travels through one PAN to the another. For this reason, inter-mobility is thought to be more reliable than intra-mobility. The following section goes through each instance in detail and shows the signalling distortion for every one.

2.1- Macro Handover or Inter-PAN Mobility in Ideal Case

The FFD recognises that the MN would leave its covering when it exceeds the very first threshold and communicates with an unique FFD in fresh PAN. As a result, FFD sends a handover text, HO, to present or former MAG (PMAG), notifying them that perhaps MN would be departing their coverage, as seen in Figure 4 (inter-mobility). The MN's ID is included in this HO package. The PMAG transmits registration notifications to the NMAG in order for the MN's ID to be recorded inside the NMAG's database. So because registration has also been completed, the NMAG is available to accept the MN and link with it immediately at that time. As a result, the NMAG awaits for the MN till MN is within the PMAG's covering, at which point the packet is following from PMAG.

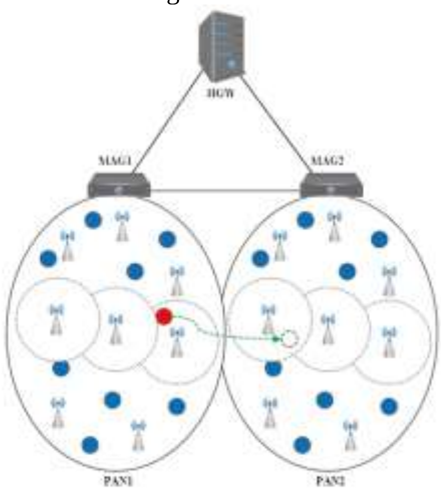

Fig. 4: inter-mobility

Once PMAG sends HO packets to NMAG, timer starts. This timer's job is to assess connection, however if link among both PMAG and MN is disrupted, MAG deletes MN enrollment out of its tables. When such MN hits second threshold, it really has passed over PMAG covering and is presently in NMAG region. The NMAG therefore sends an confirm message first to HG, instructing it to modify its table as well as respond to message. The signalling dispersion throughout the inter-mobility situation is depicted in Figure 5.

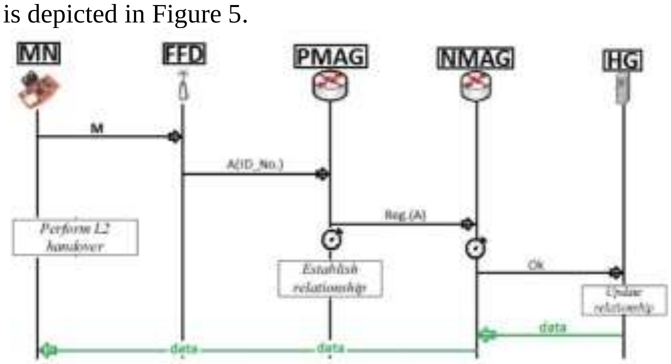

Fig. 5: Signaling distribution in “inter-mobility”

2.2- Macro Handover or Inter-PAN Mobility in Traffic Load

Figure 6 depicts traffic loading inter-mobility as the node travels through one PAN to some other. The HGW shall assess the congestion for each MAG on a regular basis and notify them. As a result, MAG1 registers whether or not there is some traffic load throughout MAG2 that also believes whether or not there is some traffic burden in MAG1. The traffic load criterion was fixed at 85%, which means that when the traffic load mostly in destiny MAG surpasses this proportion, this event shall be activated. Assuming a MN is going from MAG1 towards MAG2, as well as MAG2 does have a traffic load about 90%, MAG1 and MAG2 are aware of the traffic burden; as a result, MAG2 issues an order immediately to the nearby FFD node mostly to MAG1.

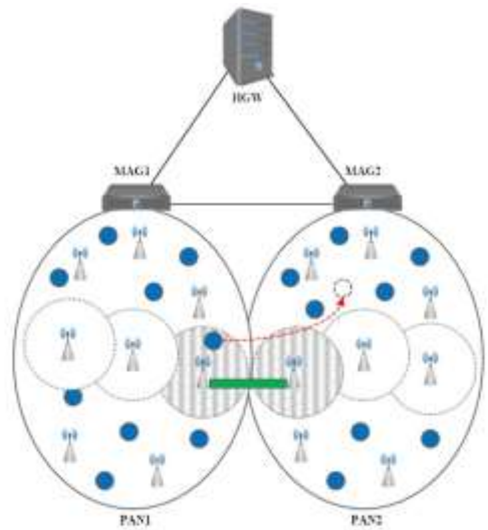

Fig. 6: Inter-mobility with traffic load

Once MAG1 senses that a MN is approaching to MAG2 but also that MAG2 does have traffic load, it sends a packet through MAG2 to nearby FFD. The instructions in these packets are to build a bridge amongst FFD1 in MAG1 as well as FFD2 in MAG2. Any node shifting through MAG1 to MAG2 after that shall broadcast message and packet towards both FFDs. Because when MN enters MAG2's covering, target in MN table would not changed, and the message will continue to be transmitted to MAG1 that would also convey packet to the migrating MN across FFD1 and FFD2. The signalling pattern throughout the inter-mobility loading traffic situation is depicted in Figure 7.

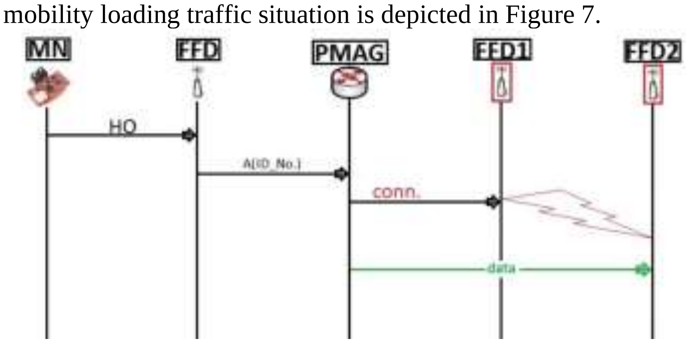

Fig. 7: Signaling distribution in “inter-mobility” in load traffic case

VI. EVALUATION OF PERFORMANCE

1- Analytical

Two situations guide the creation of an analysing module. When ever a node goes through one FFD to some other at similar PAN, this is the initial scenario (intra-PAN mobility). Unless a node transfers through one FFD to the next in another PAN, the second case occurs (inter-PAN mobility). The analytics modules are run using MATLAB simulations, although it doesn't enable IPv6 or 6LoWPAN. As just a result, in order to obtain the outcomes, this research paper uses the equations given in the next part to construct the system. Furthermore, all of the parameters for such equations are supplied by the logfile obtained in the NS2 simulations, which is used by MATLAB specifications. Because when NS2 simulator starts running, a logs file is generated quickly. The distances across the FFD and RFD nodes, both L2 and L3 delay rates, and also the speed within every movement node are all contained in this entry. As a result, the MATLAB specifications extract the handover delay, handover prices, and packet drop from the file system. The equations [9] are used in this work, with a little update that includes the addition of a new parameter. Furthermore, this method doesn't require an acknowledge message; when FFD sends a packet to the MAGs, an automated timer is started and used as an acknowledgement. As an outcome, the signalling will be minimised because all of the $t_{HO\text{-}ACK}$ in this design would be zero. The next section goes over each of them in depth, including the settings within each.

1.2- Intra-PAN mobility analytical

L2 and L3 could be used to estimate the intra-PAN delay based just on signal distribution depicted in Figure 3. Because L3 is started before L2, they both work at the same time. In equation (1) T_{intra} is indeed the handover delay, $T_{\text{L3-intra}}$ seems to be intra-PAN L3 delay, TL2-intra seems to be intra-PAN L2 delay, as well as t_{HO} and $t_{\text{HO-Ack}}$ are the amount of time it takes to communicate and retain the packet amongst the FFD nodes, respectively [9]. The range amongst the existing FFD as well as MAG, $D_{\text{FFD-PMAG}}$, is determined by the hop count across them. $D_{\text{FFD-RFD}}$ is the range connecting sensor nodes MN with RFD (PFFD).

$$T_{intra} = Max(T_{\text{L3-intra}} , T_{\text{L2-intra}}) \quad (1)$$

$$T_{\text{L3-intra}} = (t_{HO} + t_{HO\text{-}Ack})* D_{\text{FFD-PMAG}}$$

$$T_{\text{L2-intra}} = (L_2 + t_{HO}* D_{\text{FFD-RFD}}$$

The packet drop occurred since the L2 or L3 completing the handover procedure first, whiles the second continued. The packet drop is also affected by the covering radius of the FFD and the mobility velocity of the RFD. P_{inter} is indeed the packet drop, r seems to be the radio communication, as well as v is the RFD or MN speed, according to equation (2) [9].

$$P_{\text{inter}} = \frac{|T_{L3} - T_{L2}|}{r/v} \quad (2)$$

The L_3 as well as L_2 handover prices make up the entire handover price. The terms C_{HO} and $C_{HO\text{-}Ack}$ in equation (3) [9] reflect the price of the packet sent across FFD nodes.

$$C_{intra} = C_{L3\text{-}intra} + C_{L2\text{-}intra} \quad (3)$$
$$C_{L3\text{-}intra} = (C_{HO} + C_{HO\text{-}Ack})* D_{FFD\text{-}PMAG}$$
$$C_{L2\text{-}intra} = C_{HO}* C_{FFD\text{-}RFD}$$

1.3- Mobility Analytical of Inter-PAN

The L_2 as well as L_3 could be used to determine the intra-PAN delay based on the signal dispersion in Figure 5. Because L3 is started and completed before L2, they both run at the same time. $D_{FFD\text{-}NFFD}$ seems to be the range among both the previous FFD as well as the fresh FFD with which the RFD would attach in formula (4). $D_{NMAG\text{-}HGW}$ is perhaps the range amongst the MAG as well as HGW. With [9], the component $D_{NMAG\text{-}PMAG}$ was introduced to the equations, and is often utilized to calculate range between prior MAG and the newer MAG (PMAG-NMAG) and in equation (6).

$$T_{inter} = Max(T_{\text{L3-inter}} , T_{\text{L2-inter}}) \quad (4)$$
$$T_{L3\text{-}inter} = (t_{HO} + t_{HO\text{-}Ack})* D_{FFD\text{-}PMAG} + (t_{HO} + t_{HO\text{-}Ack})* D_{FFD\text{-}NFFD} + (t_{HO} + t_{HO\text{-}Ack})* D_{NMAG\text{-}HGW} + (t_{HO} + t_{HO\text{-}Ack})* D_{NMAG\text{-}PMAG}$$
$$C_{L3\text{-}inter} = (C_{HO} + C_{HO\text{-}Ack})* D_{FFD\text{-}PMAG}$$
$$T_{L2\text{-}inter} = L_2 + t_{HO} * D_{FFD\text{-}RFD}$$

The packet drop can also arise when L_2 or L_3 completes the handover procedure first as the second continues. The drop is also affected by the covering radius of the FFD as well as the movement velocity of the RFD. P_{inter} is packet drop; r seems to be radio communication, while v is indeed RFD or MN speed [17], according to equation (5).

$$P_{\text{inter}} = \frac{|T_{L3} - T_{L2}|}{r/v} \quad (5)$$

The L3 as well as L2 handover prices make up the total handover price. C_{HO} and $C_{HO\text{-}Ack}$ in equation (3.6) relate to the expense of the packet sent amongst FFD nodes.

$$C_{inter} = C_{L3\text{-}inter} + C_{L2\text{-}inter} \quad (6)$$
$$C_{L3\text{-}inter} = (C_{HO} + C_{HO\text{-}Ack})* D_{FFD\text{-}PMAG}+(C_{HO} + C_{HO\text{-}Ack})*D_{FFD\text{-}NFFD}+(C_{HO} + C_{HO\text{-}Ack})* D_{NMAG\text{-}HGW} + (C_{HO} + C_{HO\text{-}Ack})* D_{NMAG\text{-}PMAG}$$
$$C_{L2\text{-}inter} = C_{HO}* C_{FFD\text{-}RFD} + C_{L2}$$

2- Simulation

This portion explains simulation approach utilized in this research to analyze and validate suggested approach. The whole simulation has been performed to check the suggested technique's handover effectiveness, like handover delay, packet drop, including handover price, which is dependent on the number of thresholds. IPv6 and the 6LoWPAN standard are supported by the simulation. As a result, the NS-2 is used in this research to analyze performance.

Though Network Simulator versions is NS-2. It is programmed in C++ as well as OTcl and is most effective for emulating local and broad area networks. The most essential feature is that even the NS-2 supports 6LoWPAN, IPv6, TCP, FTP, UDP, Web, CBR, Telnet, and VBR mechanisms. The NS-2 could also build networks, including links & nodes, traffic, as well as connections. As a result, NS-2 is being used as a projects simulator in this research.

The project is implemented using the NS-2 simulation in this research. Although IEEE 802.15.4 is utilised in 6LoWPAN, the above simulation uses this for layer 2 (L2) standard. Table 1 lists the parameters utilised in this simulation. This design makes use of the random motion modules. In addition, the mobility speed ranges is selected between 10.0 and 30.0 m/s since the greatest runner could run at 30.0 km/h or 100.0 metres in 12 seconds [16, 17]. According to [9], the nodes' maximal communication diameter is 200.0 metres.

The scenario is divided into four segments, depending upon the needs. First is the static FFD node, which would be responsible for identifying any movable nodes, either RFD or MN. The FFD also serves as a connector across MAG and RFD. The second component is also a RFD node, which collects data & information from the surroundings and sends this to MAG. Such nodes can move around and modify their places. Another third node seems to be MAG node, so in this situation, the two MAGs serve like Edge router nodes administrators while also acting as a link across both FFD and HGW nodes. The fourth component is HGW, which connects network to internet. The HGW therefore knows where each node for both PANs is located. One HGW, two MAGs, 50 stationary FFDs, and 250 moving RFDs or mobility sensors are used in the scenarios, and they roam randomly within one PAN either between others. Since they monitors display the FFD motions, the FFD nodes perform all activities. Furthermore, the FFD makes the decision about as to if or not RFD covers it.

Description of Parameter	Values of Parameter
Area for simulation	1000.0m×1000.0m
Model of mobility	Random waypoint
Speed (v)	[10.0 m/s, 30.0 m/s]
Radius of communication (r)	[60.0 m, 100.0 m]
Total FFD nodes	50.0
Total RFD nodes	250.0
Rounds	10.0
Time for simulation	500.0 s

Table (1) parameters

The 6LoWPAN's effectiveness is defined on the basis of handover delay, packet drop, and changeover prices. The handover latency approach that aims to reduce handover delay and increase network lifetime, was previously discussed. In this part, all of conclusions are reviewed and contrasted to related works or even the benchmarks. FFD node setup and cross-layer mobility that rely on Layer 2 but also Layer 3 have been used to assure satisfactory performance within our scenario. The suggested technique in this study gives a good performance assessment for the 6LoWPAN standard's handover latency, as indicated by the outcomes in the next subsection. Each network would perceive an MN that hops from one point to the next and pauses for many milliseconds while seek other base station to commence communications a drawback. This connection gap generates a delay, therefore diminishes the network's lifetime and has an impact on packet drop rates and signalling costs. As a consequence, the results suggest that new strategy, which would be more effective than the prior one, could minimize handover latency.

The delay time is calculated using the model's formulas (1) and (2) for calculating delay typically occurs under Layer 2 through Layer 3. (4). Furthermore, by evaluating time required to detach and reattach node with yet other base station or some other FFD node operating as base station, packet drop and changeover expenses can be estimated concurrently.

The handover delay within intra-PAN mobility (whenever RFD or MN moves throughout one place to another within same PAN) is depicted in Figure 8a, with both the red line representing simulation benchmark outcome and blue line representing the experimental data, with a 3.8 percent error rate. The calculation result is clearly similar to or identical to the prior outcomes. Whenever the error rate is 0.76 percent, Figure 8b displays handover delay time during inter-PAN mobility (whenever node RFD as well as MN changes location through one PAN to some other PAN). The pace of the nodes, and also the simulation, are factors in the analytical model. The speed restriction in this investigation varies from 10.0 to 30.0 m/s. RFDs have a communication diameter of 120.0 metres, whilst FFDs and MAGs have a diameter of 200 metres. It is clear that as network speed improves, network stability decreases.

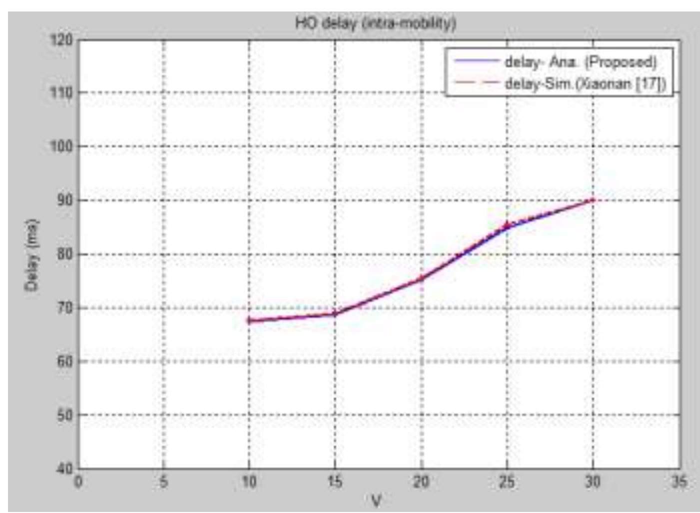

Fig .8a: Speed based HO delay intra-mobility

According to the preceding figures (8a & 8b), packet drop increases as the handover latency increased, and this happens whenever the node approaches the crucial zone, i.e., the disconnect zone. The RFD or MN detaches from the preceding base station or FFD at about this disconnecting region and begins a searching for the nearby base station as well as FFD.

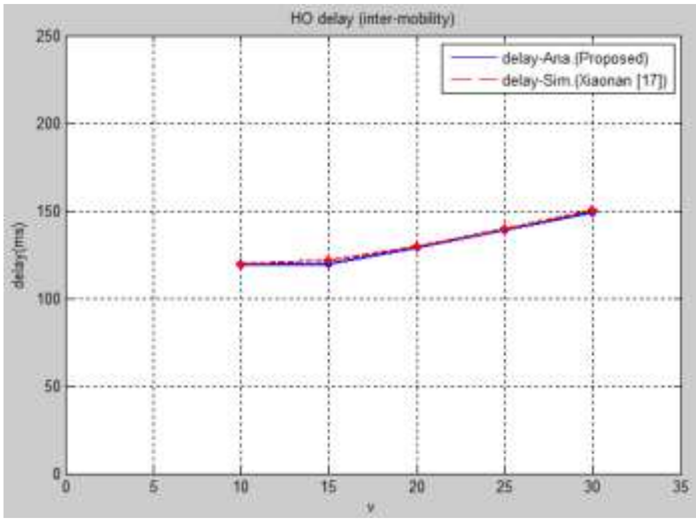

Fig. 8b: Speed based HO delay inter-mobility

The Layer 2 is responsible for motion identification, Care of Address (CoA) setting, Duplicate Address Detection (DAD), and registering delay, whereas Layer 3 is responsible for channel scan, authorization, and connection. As a result, these two layers account for nearly all of the delay. The 6LoWPAN networks, on the other hand, doesn't even use COA as the nodes are using the information channel to go out to Layer 2; as a result, the node doesn't want to scan every channels while in movement. Figure 8c depicts packet loss as a function of node speed in intra-PAN mobility, with a 1.91 percent error rate across simulation as well as analytical results, whereas Figure 8d depicts packet loss as a function of node speed during inter-PAN mobility, with such a 5.41 percent error rate.

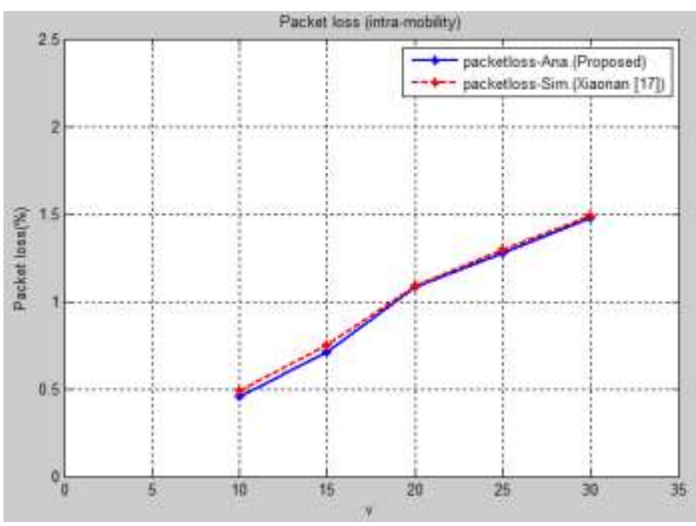

Fig. 8c: Packet loss intra-mobility

When it comes to handover costs, it's self-evident that if packet-loss rate rises, so will signalling prices. It is as the mobility nodes send packets every millisecond, therefore whenever the MN or RFD enters the disconnect zone, the former kept separate from the prior FFD, and the MN would continue to deliver the packet despite the fact that there is no FFD contacts to collect it.

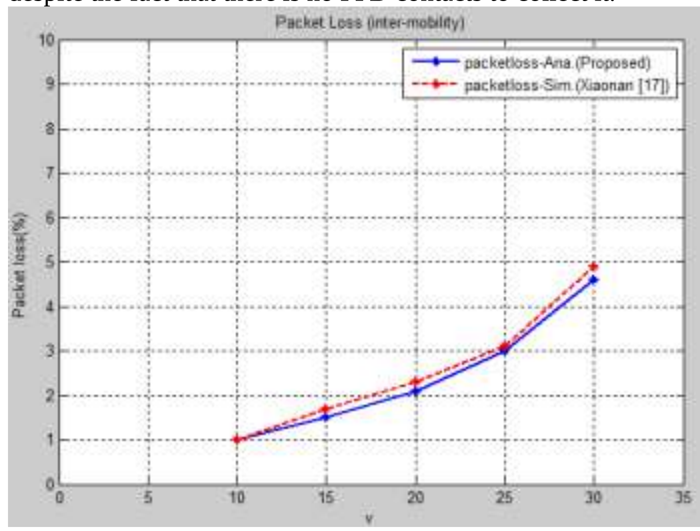

Fig. 8d: Packet loss inter-mobility

As a result, as soon since there is no connectivity amongst the RFD and FFD, the data packets or messages will grow. Figures 8e and 8f depict the signalling price of intra-PAN mobility as well as inter-PAN mobility, correspondingly, with error rates of 0.93 percent and 2.96 percent. Whenever the MN's speed improves, it takes longer to discover and connect with nearby FFDs, increasing the risk that now the MN will lose the contact due to the increased speed.

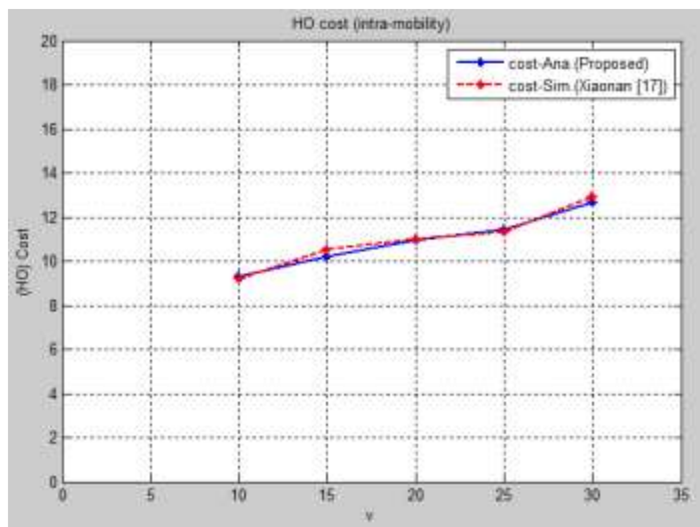

Fig. 8e: HO cost intra-mobility

The prior work is noteworthy in that it minimises run time across both Layer 2 & Layer 3 in order to improve and optimise handover latency effectiveness. The major goal of this research is to figure out how to record moving nodes prior they reached the disconnecting zone. As previously noted, the solution is obtained by establishing two threshold values.

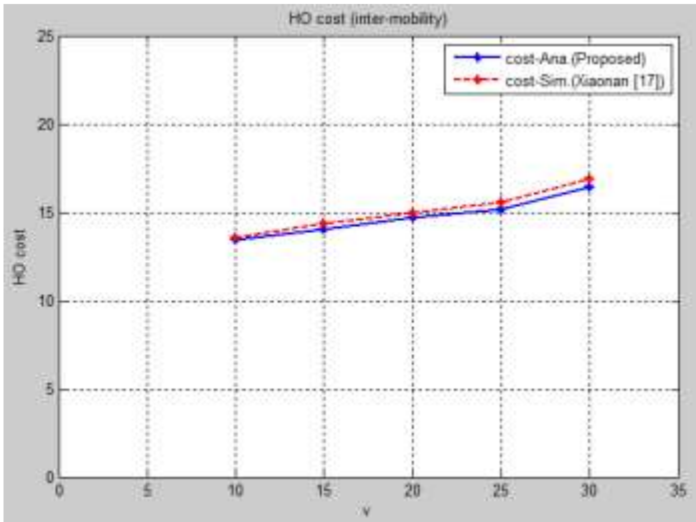

Fig. 8f: HO cost inter-mobility

This technique demonstrates that it can improve 6LoWPAN handover latency effectiveness while also lowering HO delay, HO price, and packet drop. Figure 9a depicts Handover delay duration when MN travels within similar PAN (intra-PAN), whilst Figure 9b depicts delay time whenever MN goes between PANs. Furthermore, the error rates for analytic and simulation outcomes are 3.34 percent and 0.38 percent, correspondingly. In addition, a certain analytical formula that was utilised throughout the validation implementation was employed to check the correctness in this execution.

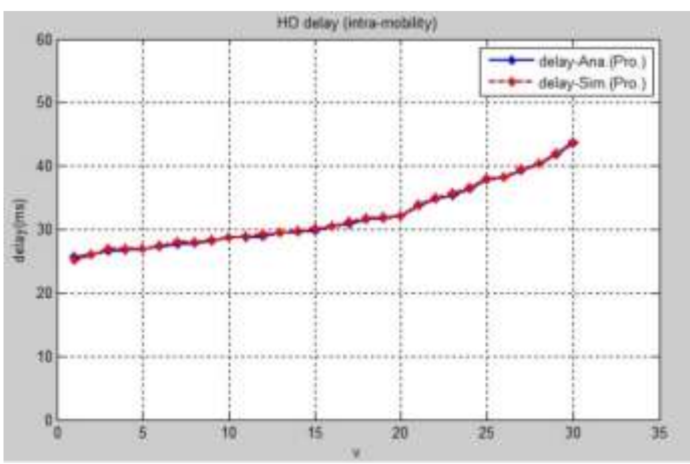

Fig. 9a: Speed based HO delay intra-mobility

Pre-registration seems to be the cause for the reducing the delay time. Whenever the MN moves past the first threshold, current FFD shall send all of registration info towards next FFD with which MN would link. The MN itself is connected to the present FFD at this moment, however when it over the second threshold, it signifies the MN has travelled a long distance and the link amongst them is no longer stable. As a response, the current FFD detaches the link, and the MN attaches to the next FFD since all infrastructures already finished because when node was underneath the first FFD, thus they don't want to authenticate or perform any research to find the closest FFD.

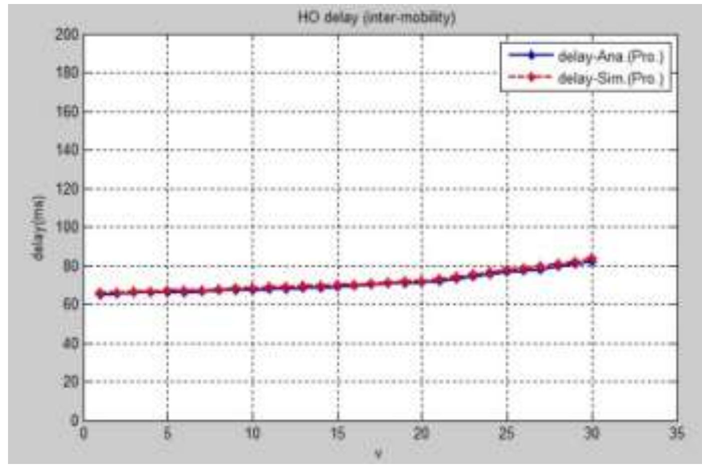

Fig. 9b: Speed based HO delay inter-mobility

The handover delays generally inversely related to packet drop; whenever handover time decreases, packet drop decreases as well, because of node no longer needs to wait for the registration to finish. As a result, the node attaches, as well as the signal's packet drop is decreased, as shown in Figures 9c and 9d, in which the difference in packet loss as well as way it is decreased is visible. Furthermore, the intra-PAN error bit as 1.84 percent, whereas the inter-PAN error bit equals 0.63 percent.

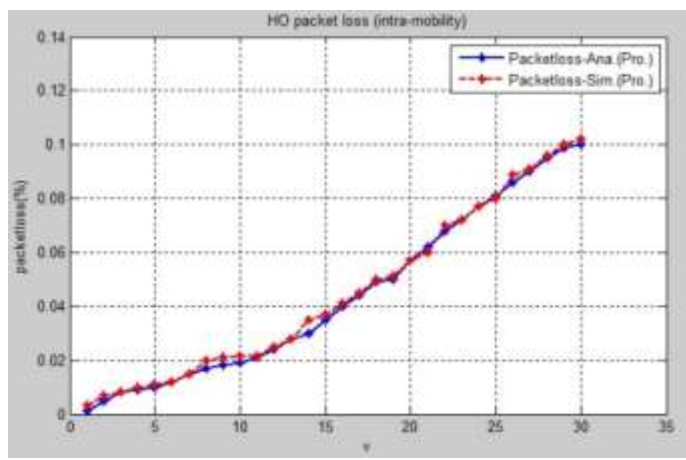

Fig. 9c: Intra-mobility packet loss

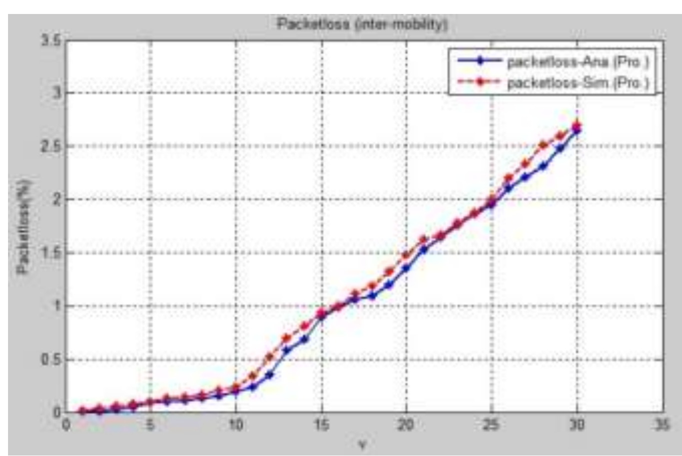

Fig. 9d: Inter-mobility packet loss

The cost of handover is also minimised in our suggested approach. Since node MN doesn't really transmit the message towards the next FFD unless it enters the fresh FFD range, there is no significant loss of packets or messages. Furthermore, because registration was already finished when the MN approaches a new FFD, it attaches, ensuring that practically all packets reached their destination. Figures 9e and 9f show intra-PAN mobility with such a 0.68 percent error rate as well as inter-PAN mobility with a 0.41 percent error rate.

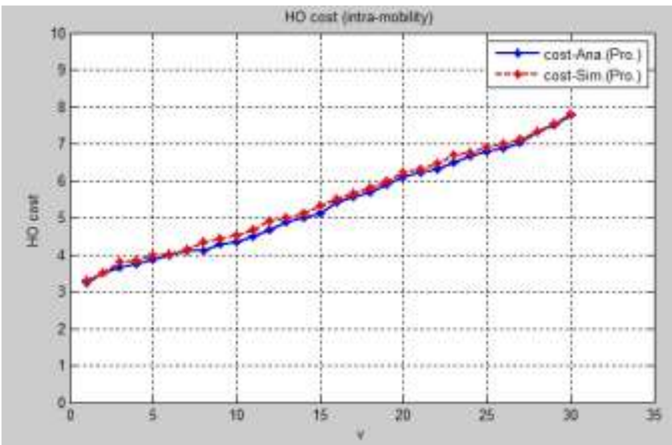

Fig. 9e: Intra-mobility of HO cost

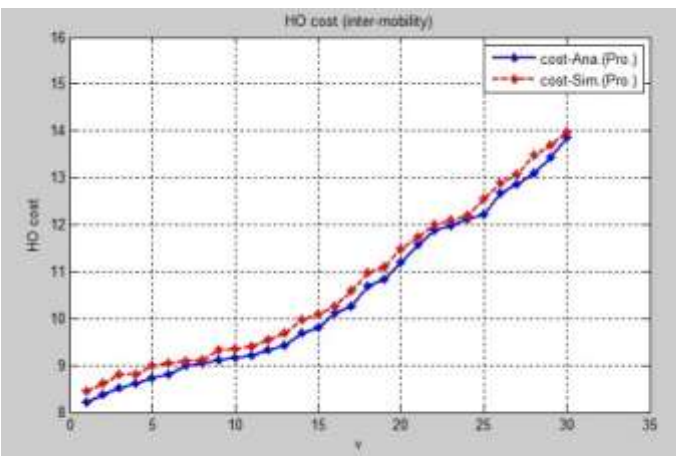

Fig. 9f: Inter-mobility of HO cost

VIII. TRAFFIC LOAD IMPACTS

The traffic load scenarios will be used when MN transfers through one PAN towards another but there occurs a traffic load in destinations PAN. This node has no effect on the PAN destinations or MAG2 when the traffic load situation is activated. In many other words, the MAG2 does neither improve or reduce, but the MN already covered by the MAG2 continues linked to MAG1 until the MAG2's traffic load drops. Since this HG has indeed sent another information registration to the MAG2, the MN can then detach from the MAG1 and stay connected to the MAG2. As an outcome, the MN has no effect on the MAG2, allowing it to continue transmitting and receiving packets.

IX. PERFORMANCE AGAINST RELATED WORKS

Ultimately, three references were chosen to compare the findings to previous research. The first is the Xionian point of reference [9], which is used in this work. The contrast between the outcomes and the prior work is clearly visible mostly in second (SMH) [17] through third (6LoWMSN) [18] ones. Figure 10a shows the difference in handover delay among both our result and earlier work. Changeover delay was decreased by 43.84 percent, packet drop was decreased by 43.76 percent (Figure 10b), and handover cost was lowered by 24.93 percent using the strategy utilised in this research (Figure 10c).

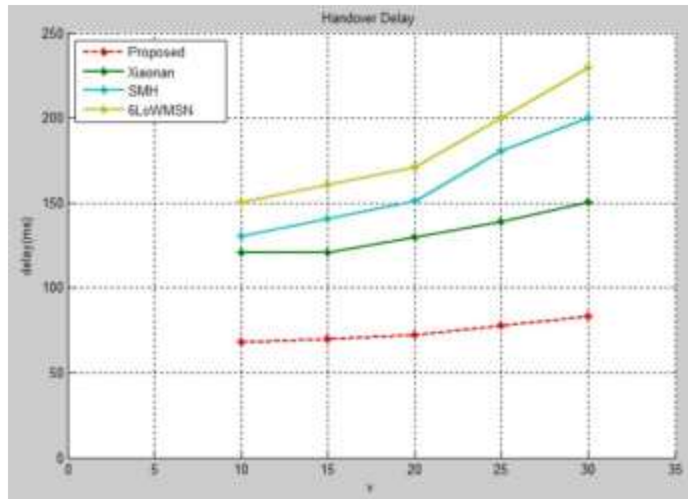

Fig. 10a: Handover delay comparison based on speed

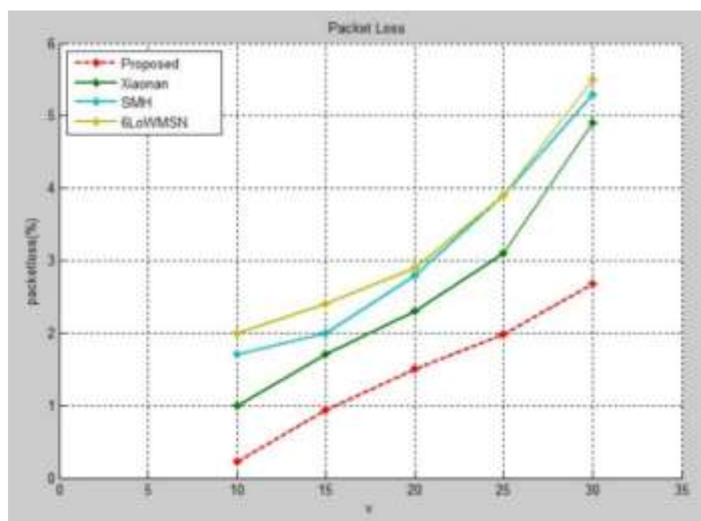

Fig. 10b: Packet loss rate comparison based on speed

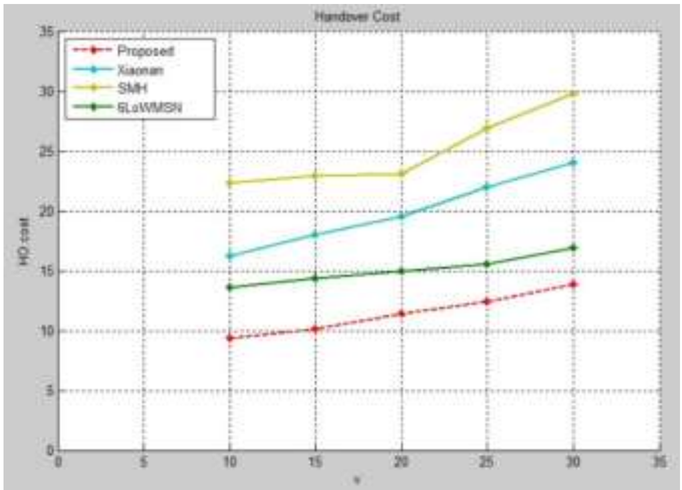

Fig. 10c: Handover cost comparison based on speed

X. CONCLUSION

The study focused on handover delay of the 6LoWPAN standard and how it might be improved to achieve a valid performance assessment that allows the system to accommodate mobile devices. The findings suggest that the approach can enhance handover latency underneath the 6LoWPAN protocol, as shown in chapters 3 and 4. Changeover delay, packet drop, and handover price were three key aspects of handover latency. We could reduce the time it takes for a mobile device to travel through one PAN to another or inside the similar PAN utilizing our technology, as well as packet loss & handover expenses. Disconnect as well as reconnect criteria, as well as altering the threshold number, are used in this approach. Furthermore, by utilising L2 and L3, the method allows all operations to be completed while the mobile node would be in a stable state, as opposed to prior work that required mobile node to touch disconnect range before initiating L2 and L3 procedures. Furthermore, we discovered that prior simulation approach, which uses the FFD as a link among both RFD and ER, but RFD as sensor nodes, is superior at minimising control messages and extending network's lifetime. As a result, RFD activity on sensing would be short, and FFD will just control the RFDs.

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