A Study for Hop Count on the Ad-Hoc of Wireless Communication

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***Abstract*— MIL-STD-188-220, a typical Ad-Hoc protocol frequently used by the military, utilizes an FM radio to perform Relays. The function of the SDR (Source Directed Relay), which refers to the routing information table interchanged to the function of the Topology Update, sets up a path to reach a receiver. Due to the low speed interface of the FM radio, we designed a simulation employing OPNET to determine the adequate Hop Counts. This simulation was also able to determine the proper operational and environmental conditions.**

***Keywords*— Hop Count, Ad-Hoc, MIL-STD-188-220, Source Direct Relay, Topology Update**

I. Introduction

We simulated the representative Ad-Hoc protocol MIL-STD-188-220 that is used in the US Armed Forces and the Korean Armed Forces. Using OPENT, a network simulation instrument, we also implemented a protocol to measure network performance.

Due to the low transmission speed of the FM radio and the inadequate communication environment of long Blind Time, the number of nodes within the network was limited. Consequently, when we used the FM radio, it was difficult to determine the adequate Hop Count limit. To address this issue, this study designed and implemented nodes to simulate the MIL-STD-188-220 protocol within OPNET and performed the simulation to measure the adequate Hop Counts as an amount of traffic fixed to an operational environment. Before performing the simulation, we determined that there were differences in performance because algorisms that corresponded to NAC (Network Access Control) were operating in MAC. Gregory [2] states that R-NAD (Random Network Access Delay) has better performance than P-NAD (Priority Network Access Delay). Thus, once R-NAD and DAP-NAD (Deterministic Adaptable Priority Network Access Delay) were operational, we respectively implemented two of NAD's functions to verify a difference in the network performance.

We obtained the proper number of nodes that necessary for the network simulation before determining the adequate Hop Counts because adequate Hop Counts vary according to changes in the number of nodes.

Section II describes SDR and Topology Update' functions in a network layer as it relates to Hop Counts in the MIL-STD-188-220 protocol. Section III explains a node model, a process model, and a traffic model that are implemented by OPNET. Section IV describes the performance process and results of the simulation that determined the proper number of nodes. Section V details the simulation results in order to figure out the adequate number of Hops. Section VI provides a conclusion that is based on the results of the simulation.

II. The Functions of SDR and Topology Update

As shown in Figure 1, MIL-STD-188-220 protocol's intranet layers consist of NP (Exchange Network Parameters), Topology Update, SDR (Source Directed Relay), Topology Update Timer, Topology Update Request Timer, and End-to-End Ack Timer.

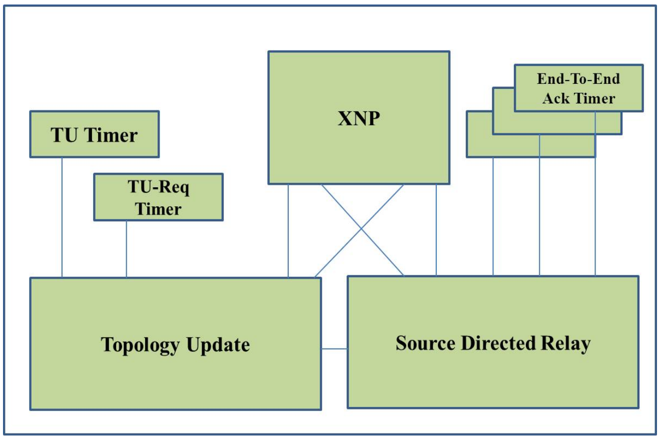

Figure 1. Intranet Layer Architecture

In Figure 1, the XNP module performs a procedure for network management that is used for the join and goodbye functions. It was utilized for the purpose of sharing a network parameter.

A. SDR

SDR provides procedures that relay packets from a source to more than one destination. Using the Topology Update information, the source calculated a path to reach each destination.

The particular path for each destination was included in an intranet header. If paths for more than two destinations shared links, then the two paths were integrated.

As a result, the common nodes on the path had to be non-existent. Figure 2 describes the network configuration that relays the signal from the Source node to the Destination node.

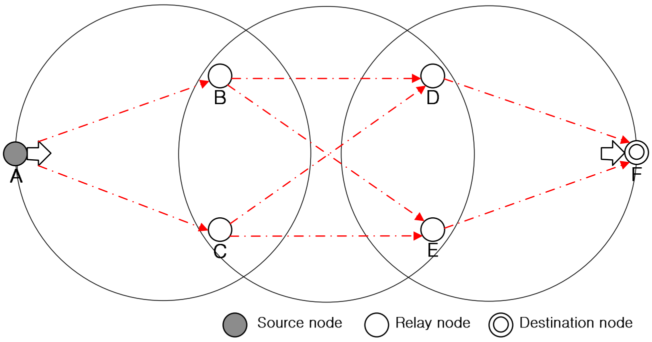

Figure 2. Sample Intranet

End-To-End Ack was formed by the final destination node when the intranet header, which had the Ack bit set to the Destination Status Byte for destination, was received. End-To-End Ack's source mode and path among destinations became reversed. After which, the destinations in the middle of the path disappeared. The DES within the Status Byte of every forwarder was set to 0 and carried out relay only. The intranet information is shown in Table 1.

TABLE 1. THE VALUE ARE ASSIGNED TO THE INTRANET HEADER

Field	Value
Message Type	4 (IP Packet)
Header Length	12 Octets
Max Hop Count	3 (Distance from node A to F)
Originator Address	4 (Node A)
Status Byte 1	00001001 (Ack=No, DES=No, REL=Yes, DIS=1)
Destination 1	5 (Node B)
Status Byte 2	00001010 (Ack=No, DES=No, REL=Yes, DIS=2)
Destination 2	7 (Node D)
Status Byte 3	01000011 (Ack=No, DES=Yes, REL=No, DIS=3)
Destination 3	9 (Node F)

B. Topology Update

The nodes in the network were able to obtain Topology information by multicasting their individual routing tree to neighbouring nodes. As shown in Figure 3, when the link is present on the network, it is assumed that the routing trees for every node contained the closest neighbours at first. At this time, if node C multicast its Topology to all off the nodes away from 1 Hop, all neighbouring nodes made a Topology table by adding C's routing tree to theirs. The resulting tree was called the Full Tree. After eliminating the overlapping information, the Sparse Routing Tree was made in order to exchange information with neighbouring nodes.

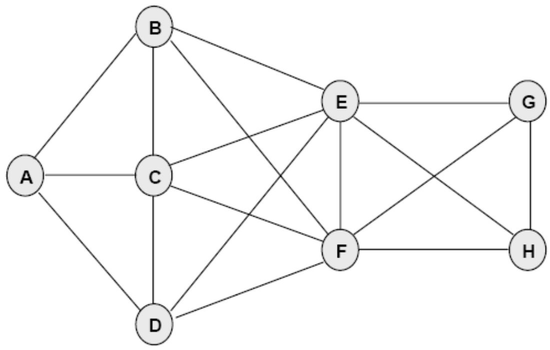

Figure 3. Link diagram of sample network

III. DESIGN FOR OPNET MODELLING

As shown in Figure 4, we implemented an Application Layer, a Network Layer, an Intranet Layer, a Data Link Layer, and a Physical Layer as mainly mandatory factors of the specification for modelling the MIL-STD-188-220 protocol. The white box utilized the COTS Model, the yellow boxes were mandatory functions, the green boxes were selective functions, and the red boxes were functions implemented by the researchers.

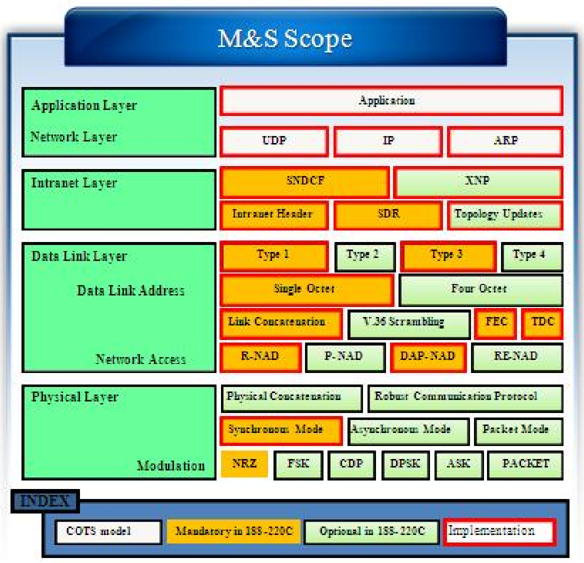

Figure 4. M&S Scope

Figure 5 displays a configuration of the nodes model in the OPNET and the function that each layer performs. The Application Layer generated message and set the TOS bit

(Type of Service). The Intranet Layer had four functions: determining a destination, obtaining the value of the TOS field, making intranet header and setting the path, and carrying out the Relay function. The Data Link Layer performed DAP-NAD and R-NAD and also carried out both Type 1 and Type 3 procedures. The Physical Layer generated by Physical PDU controlled the Tx/Rx Timer.

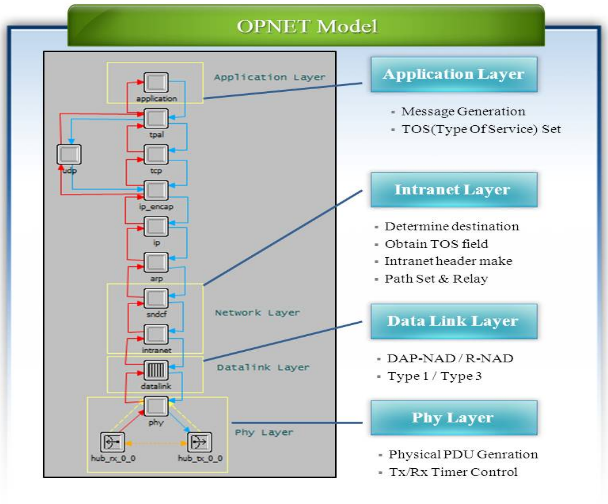

Figure 5. Node Model in the OPNET

IV. Simulation and Result of The Adequate Number of Nodes

In order to determine adequate Hop Counts, we had to find out the proper number of nodes that could consist of the network because adequate Hop Counts were different every time the number of nodes was changed. Figure 6 shows that the number of nodes increased when creating scenario on OPNET.

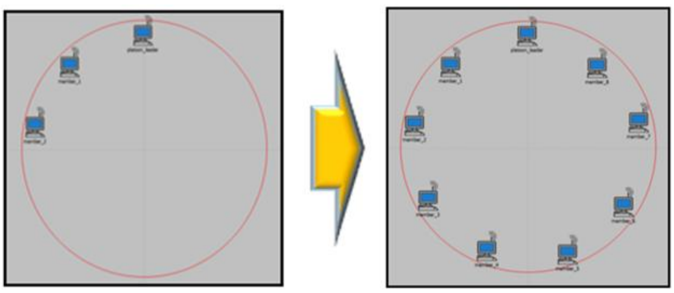

Figure 6. Node Position on OPNET

Figure 7 and 8 shows the simulation results of the R-NAD operation when 1 Hop consists of a network as is shown in Figure 6.

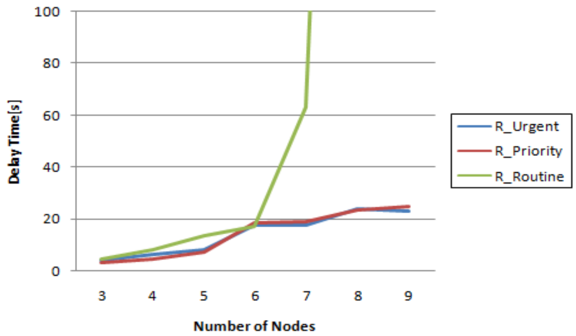

Figure 7. Delay time due to change in the number of nodes on R-NAD

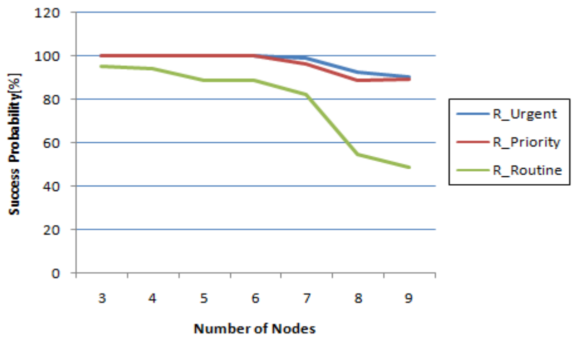

Figure 8. Success rate due to change in the number of nodes on R-NAD

Figures 7 and 8 indicate the delay time of messages and the probability of success on R-NAD. As shown in the figures above, when there were more than 6 nodes, the message of the Routine had noticeably worse delay times and probability of success.

Figure 9 and 10 indicate the simulation results of the DAP-NAD operation.

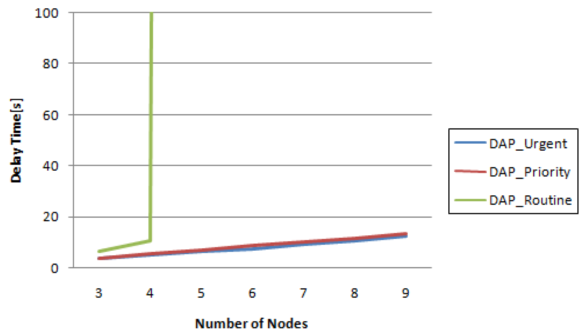

Figure 9. Delay time due to change in the number of nodes on DAP-NAD

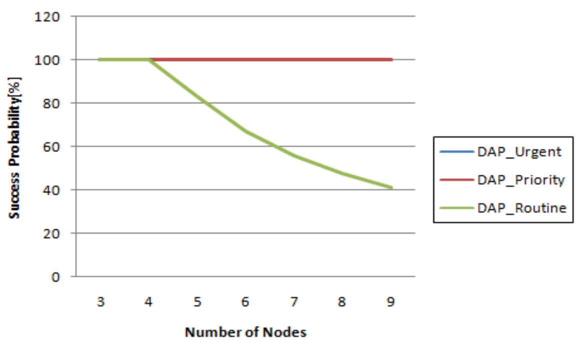

Figure 10. Success rate due to change in the number of nodes on DAP-NAD

As shown in Figure 9 and 10, if the network consists of more than 4 nodes during the DAP-NAD operation, then delay time will be drastically increased

V. Simulation and Result on Adequate Hop Count

The components of the simulation with the adequate Hop Counts drawn in the network using MIL-STD-188-220 protocol were set as follows.

A. Assumption Matters

The number of nodes consisted of Topology adapted from a simulation result of the proper number of the nodes.

The scenario consisted of R-NAD with 1 to 5 Hops and DAP-NAD with 1 to 3 Hops. In order to progress the simulation, R-NAD applied 6 units (1 platoon leader node and 5 platoon crew nodes) and DAP-NAD applied 4 units (1 platoon leader node and 3 platoon crew nodes).

B. Traffic set-up

Traffic was equally set in all scenarios.

- Types of Traffic
- The different types of traffic were Urgent, Priority, and Routine.
- Direction of Traffic
- The direction of traffic was set to only a vertical report. In most cases, platoon crews did not report to other crews and the platoon header only sent the platoon crew message and vice versa.
  - ■ Platoon leader node: sent every platoon crew node an Urgent message by multicast
  - ■ Platoon member node: sent platoon header node Priority and Routine message by unicast.
- Traffic Interval and Size
- As shown in the chart below, Traffic interval and size caused an Urgent message, a Priority message, and a Routine message.

TABLE 2. Traffic Interval and Size

Traffic Type	Interval (sec)	Size (bit)
Urgent	900 ~ 2400	98
Priority	900 ~ 2400	2206
Routine	60	250

- Delay Time between Hops
- The delay time between Hops applied the Fixed Factor and the Proportional Factor among parameters that were used in a MIL-STD-188-220 standard document.
- Delay Time[s]
  = (Proportional Factor * Hop) + Fixed Factor
  = (60 * Hop Count) + 30
- How to Measure the Result
- The result of the simulation measured message delay time and probability of success between platoon header node and platoon crew node with the maximum Hop Counts. It also measured them separately as types of message. The average was found out by measuring the same scenario in the other seed value five times.

C. Simulation Result

As shown in the Figures below, the simulation obtained a delay time and a probability of success on R-NAD, as well as a delay time and probability of success on DAP-NAD. As shown in Figure 11 and 12, the delay time on R-NAD increased in the order of Urgent-Priority-Routine message, drastically growing over 3 Hop Counts.

The probability of success decreased as the Hop Counts increased owing to having no retransmission feature in the Routine message. Particularly, it dropped below 80% over 3 Hop Counts. However, it was certain that the constant probability of success was guaranteed because the Urgent message and the Priority message had retransmitted in spite of increasing Hop Counts.

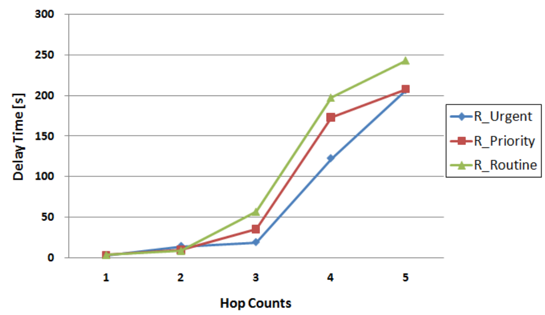

Figure 11. Delay time due to hop counts on R-NAD

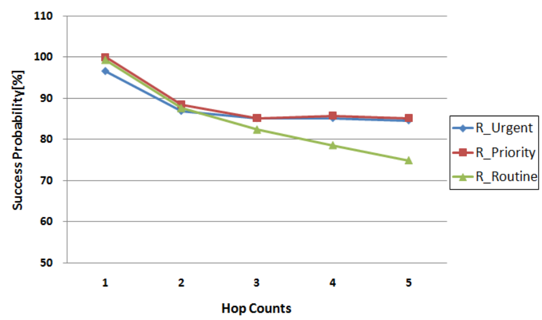

Figure 12. Success Rate due to hop counts on R-NAD

As shown in Figure 13 and 14, the delay time on DAP-NAD rapidly increased 2 Hop Counts while the probability of success sharply dropped due to NAD's feature that gave every node and message equal transmission chance. However, the probability of success on the Priority message and the Routine message decreased after 2 Hop Counts

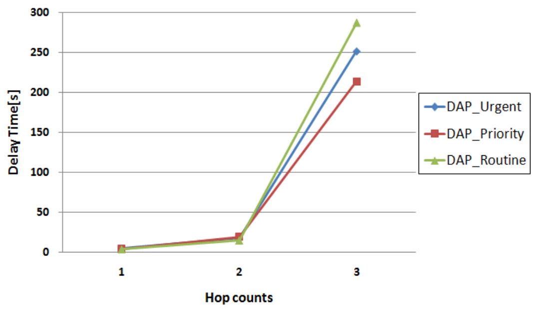

Figure 13. Delay time due to hop counts on DAP-NAD

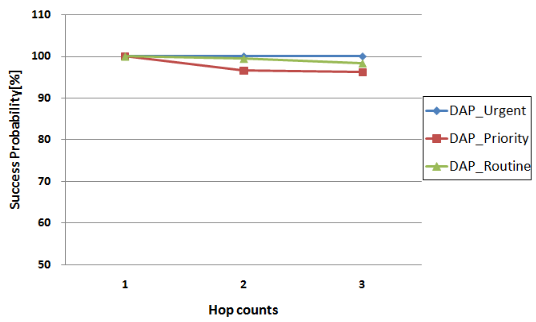

Figure 14. Delay time due to hop counts on DAP-NAD

In conclusion, it was certain that 3 Hop Counts on R-NAD and 2 Hop Counts on DAP-NAD were adequate in a military operational environment.

VI. CONCLUSIONS

The representative Ad-Hoc protocol, MIL-STD-188-220, has been used in both the US Armed Forces and the Korean Armed Forces. It supports the relay of messages by utilizing the function of Source Direct Relay and Topology Update. However, considering the speed of the FM radio, it was easy to predict that performance of the network cannot support Relays up to a maximum 7 Hop Counts, which was stated in the protocol. Accordingly, we made the number of nodes within the network limited under the low transmission speed of the FM radio, as well as an inadequate communication environment.

Thus, we implemented the simulation in order to figure out adequate Hop Counts as FM radio was used.

The simulation environment was set up based on a military operational environment where many variables were applicable. As a result of the simulation, it is possible for us to suggest adequate Hop Counts for R-NAD and DAP-NAD. The result of this paper ensures more adequate functionality of Ad-Hoc under a wide variety of environment conditions and suggests better methods for the system in different operational environments.

ACKNOWLEDGMENT

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