Simple energy saving scheme for ad-hoc network based on MIL-STD-188-220

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***Abstract*— Ad-hoc network based on MIL-STD-188-220 is utilized in military communications systems. Since capacity of battery built in military communications systems is limited, efficient energy consumption needs to be considered. For the energy consumption, this paper proposes simple energy saving scheme for ad-hoc network based on MIL-STD-188-220. The proposed scheme utilizes a time gap between preamble and data, so it allows a simple design for MIL-STD-188-220. In addition, energy consumption and slot duration of the proposed scheme are analyzed. Simulation results show good trade-off between energy saving and slot duration of the proposed scheme.**

Keywords—ad-hoc network, energy saving, MAC protocol, MIL-STD-188-220

I. INTRODUCTION

In ad-hoc network, stations communicate with each other through wireless medium. In general, the stations share same frequency band. If more than one station transmit signal concurrently, transmission collision may happen. So, medium access control (MAC) plays an important role in making the decision to transfer the information from a station to other station.

MAC plays a major role in ad-hoc network, where it considers energy consumption, the efficiency of bandwidth, slot allocation for transmission, data rate, and so on. Among them, major one of many considerations is energy consumption that influences battery life time of a station in a network. [1] has proposed power efficient MAC protocol for improving life time of network. MAC protocol that uses frame aggregation and backup channel scheme for energy efficiency has been proposed [2].

For military communications, MIL-STD-188-220 that applies to layer 2 and layer 3 of ad-hoc network has been proposed [3]. To enhance performance of MAC protocol in MIL-STD-188-220, many literatures have been proposed [4]-[7]. For QoS of voice, [4] has proposed a request message for voice to allocate slots with fixed period regardless of the number of stations. [5] has modelled and simulated an integrated voice/data ad-hoc network for one transmission in both downlink and uplink. To transmit situational awareness (SA) messages with low priority, [6] has proposed a request message for SA and sequential transmission for SA messages in order to reduce transmission delay of SA messages. Also, [7] has proposed a scheme that SA messages with low priority are aggregated with a message with high priority and small size when their destination is the same. However, energy consumption scheme for ad-hoc network based on MIL-STD-188-220 has not been reported.

Motivated by the aforementioned observations, this paper proposes simple energy consumption scheme for ad-hoc network based on MIL-STD-188-220. In addition, energy consumption and slot duration for the proposed scheme are analyzed.

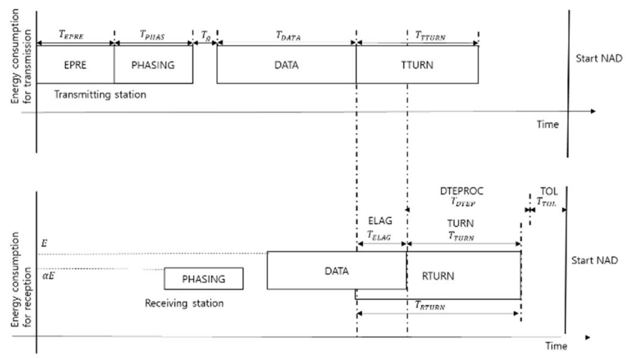

Fig. 1. Network timing model with type 1.

This paper is organized as follows: Section II briefly summarizes network timing model of MAC protocol in MIL-STD-188-220 and prioritized network access delay (P-NAD) that is one of NAD described in [3]. Section III introduces the proposed scheme and analyses of its energy consumption and slot duration, leading to simulation results and performance comparison in section IV. Finally, the paper concludes with a brief summary.

II. SYSTEM MODELS

A. Network timing model

A station is composed of data terminal equipment (DTE) and data circuit-terminating equipment (DCE). DTE performs MIL-STD-188-220, and DCE indicates communication channel of DTE. Delay from DTE via DCE to a network as well as transmission delay from a station to other station are important.

Including the above delays, network timing model parameters have been defined to insure interoperability. It is important that all stations in a network use the same parameter values. Fig. 1 shows network timing model with type 1 that a receiving station do not transmit a corresponding acknowledgement response for a reception, whereas type 3 utilizes the corresponding acknowledgement response. The network timing model parameters are as follows. Equipment preamble time (EPRE) T_{EPRE} is the time from when the DTE initiates a transmission until transmitting DTE sends its DCE the first bit of information that will be delivered to the receiving DTE. Phasing transmission time (PHASING) T_{PHAS} is the time the DTE needs to send a sequence of one and zero bits after the completion of EPRE and prior to sending the first bit of data transmission time (DATA) T_{DATA} that is the time during which the transmitting DTE sends transmit data to its DCE. Equipment lag time (ELAG) T_{ELAG} is equal to and greater than the worst-case time from when the last bits of DATA is sent by the transmitting DTE until the time when the same bit of DATA is delivered to the receiving DTE by the

B. Prioritized NAD (P-NAD)

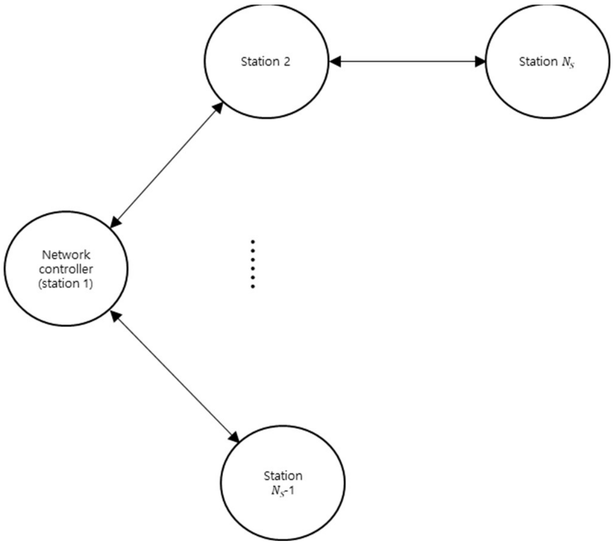

Fig. 2. Stations in a network.

receiving DCE. Turnaround time (TURN) T_{TURN} is the time from the end of ELAG until the end of TTURN or RTURN and is computed as

$$T_{TURN} = \max\big((T_{TTURN} - T_{ELAG}), (T_{RTURN} - T_{ELAG})\big), \quad (1)$$

where T_{TTURN} is called TTURN that is the time from when the transmitting DTE indicates end of transmission at the end of DATA until the transmitting DCE is ready to begin a new transmit or receive operation, while T_{RTURN} is called RTURN that is the time from when the transmitting DTE indicates end of transmission at the end of DATA until the receiving DCE is ready to begin a new transmit or receive operation. DTE ACK preparation time (DTEACK) T_{DTEA} is the time from the end of ELAG until the slowest DTE on the network can process any possible frame requiring a coupled acknowledgement, and begin sending its acknowledgement frame to its DCE. DTE processing time (DTEPROC) T_{DTEP} is the time from the end of ELAG until the slowest DTE on the network can begin sending its next transmission to its DCE after receiving DATA. DTE turnaround time (DTETURN) T_{DTET} is the time required for the DTE to begin a transmit operation when starting in a listening for receive state. Tolerance time (TOL) T_{TOL} is the time value used to compensate for variances in the actual realized lag times from a transmitting DTE to a receiving DTE. T_g is time gap between PHASING and DATA to perform energy saving that will be introduced in Section III. For conventional scheme, T_g is zero. α is coefficient of energy consumption, and its range is between zero and one. For the conventional scheme, α is equal to one. Note that synchronous mode is only considered in this paper.

Fig. 2 shows N_S stations in a network. A station is network controller that manages and controls all aspects of the network, and the other stations perform nodes. All stations in the network are able to perform source node for data transmission and relay node as well as destination nodes for data reception. The number of hops between source node and destination node is more than and equal to one. A station has access opportunity to transmit signal in a slot with certain duration. When more than two stations transmit signal in a slot, those may interfere with each other. To reduce the interference between them, network access delay (NAD) is used to provide access opportunity to a node at a slot. In all stations, NAD T_N is computed as

$$T_N = F \cdot T_B + \max(0, F-1) \cdot T_{DTET}, \quad (2)$$

where F is integer value determined by NAD, T_B is net busy detect time (NBDT).

Among various NADs, prioritized NAD (P-NAD) ensures that the highest precedence station with the highest priority message will access the network first. Each station calculates three P-NAD values, and F is calculated as

$$F = P_S + P_M + F_{IS}, \quad (3)$$

where P_S is the station priority obtained as

$$P_S = \begin{cases} R_S - 1, & \text{for initial transmission} \\ 0, & \text{for subsequent transmission,} \end{cases} \quad (4)$$

where R_S is subscriber rank determined by network controller, P_M is the message precedence obtained as

$$P_M = \begin{cases} 0, & \text{for all urgent messages} \\ N_S + 1, & \text{for all priority messages} \\ 2 \cdot (N_S + 1), & \text{for all routine messages,} \end{cases} \quad (5)$$

and F_{IS} is the initial/subsequent factor obtained as

$$F_{IS} = \begin{cases} 0, & \text{for initial transmission} \\ N_S, & \text{for subsequent transmission.} \end{cases} \quad (6)$$

III. Proposed Energy Saving Scheme and Its Performance

In Fig. 1, receiving station receives signals in PHASING and DATA. For conventional scheme, receiving station uses same energy at PHASING and DATA to demodulate them, because they are continuously received. Meanwhile, receiving station has possibility to save energy by reducing energy consumption of PHASING due to low modulation order of it. If the proposed scheme detects PHASE transmission, a receiving station has to be ready to demodulate DATA with high modulation order during T_g. In DATA, the proposed scheme use energy equal to the conventional scheme in order to demodulate DATA.

Slot durations of both the conventional scheme and the proposed scheme are analyzed as follows. For conventional scheme, slot duration is calculated as

$$T_{S,conv} = T_{EPRE} + T_{PHAS} + T_{DATA} + T_{ELAG} + \max(T_{DTEP}, T_{TURN}) + T_{TOL}, \quad (7)$$

and proposed scheme is calculated as

$$T_{S,prop} = T_{S,conv} + T_g. \quad (8)$$

Energy consumption of conventional scheme and proposed scheme are analyzed as follows. For energy consumption analysis, there are two cases: PHASING/DATA transmission and no transmission. In the case of PHASING/DATA transmission, a receiving station demodulates the PHASING. Then, a receiving station consumes energy to demodulate DATA. In the case of no transmission, a receiving station consumes energy to demodulate PHASING. Detecting no PHASING transmission, a receiving station determines no energy consumption during DATA. Based on the above description, the energy consumption of conventional scheme is calculated as

Table. 1. Values of Simulation Parameters [6], [8].

Parameter	**Value**
T_{EPRE} (msec)	40
T_{PHAS} (msec)	2
T_{TTRUN} (msec)	15
T_{RTURN} (msec)	55
T_{DTEP} (msec)	25
T_{TOL} (msec)	50
T_{ELAG} (msec)	40
E (mW/msec)	50
N_s	16
Data-rate	4.8 Kbps
CRC (bits)	16

$$E_{conv} = \frac{N_s - 1}{N_s}(T_{PHAS} + T_{DATA}) \cdot E \cdot O + \frac{N_s - 1}{N_s} E \cdot T_{PHAS} \cdot (1 - O), \quad (9)$$

where E is energy consumption for the conventional scheme in the PHASING/DATA reception and O is probability of the PHASING/DATA transmission. Note that $\frac{N_s-1}{N_s}$ needs to be considered due to P-NAD. In the case of the proposed scheme, energy consumption in PHASING is smaller than the conventional scheme and it is obtained as $\alpha \cdot E$ shown in Fig. 1, because detection and demodulation of PHASING can consume less energy than DATA due to low modulation order of PHASING. For DATA reception, the proposed scheme consumes energy that is the same as the conventional scheme. Thus, the energy consumption of the proposed scheme is calculated as

$$E_{prop} = \frac{N_s - 1}{N_s} T_{DATA} \cdot E \cdot O + \frac{N_s - 1}{N_s} \alpha \cdot E \cdot T_{PHAS}. \quad (10)$$

IV. Simulation Results

For simulations, we assume transmission success without retransmission. Table. 1 summarizes values of simulation parameters for simulations. Note that there is no error correction coding for data-rate with 4.8 Kbps [8].

Fig. 3 shows simulation results of average energy consumption for the conventional scheme and the proposed scheme. For this simulation results, message with size of 30 bytes and rate of 3600 messages/hour is used in DATA [9]. This message has low transmission probability, so energy consumption in PHASING is dominant in the simulation results. This is the reason why the proposed scheme consumes sufficiently lower energy than the conventional scheme.

Fig. 4 shows slot duration of the conventional scheme and the proposed scheme with the message that is used in Fig. 3. Slot duration of the proposed scheme is longer than the conventional scheme. However, since the slot duration of the conventional scheme is sufficiently longer than T_g, the effect of T_g in slot duration is negligible.

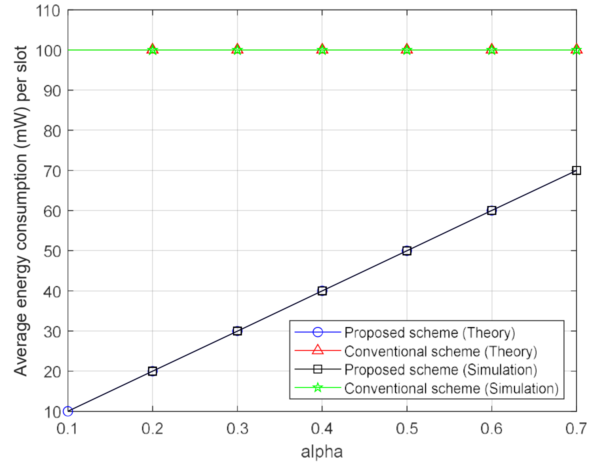

Fig. 3. Simulation results of average energy consumption for the conventional scheme and the proposed scheme.

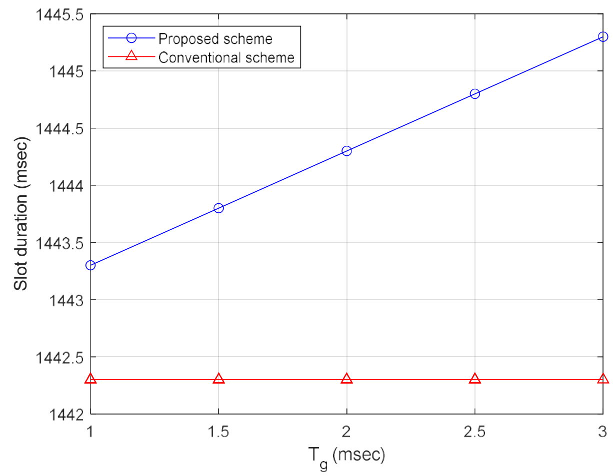

Fig. 4. Slot duration of the conventional scheme and the proposed scheme.

V. Conclusion

Simple energy saving scheme utilizing time gap between PHASING and DATA is proposed. In addition, slot duration and average energy consumption for the proposed scheme are analyzed. Simulation results show that average energy consumption of the proposed scheme is much lower than the conventional scheme, even though slot duration increment by the time gap is negligible.

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