Evaluating Hybrid Framework of VASNET and IoT in Disaster Management System

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***Abstract*—During emergency operations in Disaster Management System (DMS) for natural and man-made disasters, any breakdown in the existing information and communication technology will affect the aspect of effectiveness and efficiency on an emergency response task. For Vehicular Ad-hoc Sensor Network (VASNET), the limitation in terms of infrastructure that consists of RSU (Roadside Sensor Unit) may partially or fully destroy the post-disaster scenario. As such, performance degradation of VASNET affects the network infrastructure on high packet loss, delay, and produce a huge amount of energy consumption in DMS. Thus, modification of VASNET and integrate with Internet of Thing (IoT) technology is a must to improve and solving the current problem on VASNET technology. Therefore, the main objective of this study was to investigate the performance of the proposed modified VASNET framework integrated with IoT at DMS in terms of energy consumption and packet loss. A suggested node in the proposed framework was introduced to implement low data rate and high data rate in evaluating the proposed framework using LTE and LTE-A transmission protocol. It was found that LTE-A contributes more energy by 25.33 (mJ/Byte) compared to LTE on 20 (mJ/Byte) on a high data rate. On the other hand, in terms of low data rate, LTE-A influences the most on the proposed framework by recording 19.82(mJ/Byte), LTE only 19.33 (mJ/Byte). For packet loss, LTE shows a high packet loss rate by contributing 11.39% compared to LTE-A, which is 8.0% in terms of low data rate, and 14.80% compared to LTE-A, only 11.97% for high data rate. Consequently, LTE-A on high data rate contributes more energy consumption and LTE in packet loss on same data rate.**

Keywords*—Energy consumption; packet loss; LTE-A; VASNET; IoT

I. Introduction

With the rapid growth of smart devices in Internet of Thing (IoT) technology is estimated that in 2025, the total quantity of smart devices could rise to 1.56 billion globally [1]. As such, research interest on wireless networking communication has focused on reducing energy consumption by applying various methods.Moreover, energy dissipation could pollute our environment caused by electronic devices becoming unhealthy and significant impact on our daily lives.

In connection with this, various natural disasters like landslides, volcanoes and earthquakes may rise from year to year affecting millions of innocent human life [2]. To cope with this problem, research work was done on existing Disaster Management System (DMS) to integrate different types of wireless network technologies to be more efficient. Therefore, the integration of VASNET and IoT in DMS is introduced in this research. The interface plays the leading role in linking both VASNET and IoT in the DMS [2]. The modification of Vehicular Ad-hoc Sensor Network (VASNET) is hugely challenging in terms of protocol that used to be compatible with current IoT technologies. The modified sensor node from VASNET should be equipped with sensing, processing and transmitting the data [3] concerning Base Station (BS) in Bi-directional mode. Furthermore, the data dissemination must cover a large geographical region [4]. The sensor nodes on disaster areas can capture data in the cluster environment from the tracked region, manipulate data and broadcast to main nodes with more collection points called Gateway, actively using the interface for further data analysis or tracking location [5].

One of the critical resources in sensor nodes that affect the performance and reliability of DMS is the energy supplied [4]. The primary role of power was providing the necessary energy to achieve the mission of sensor nodes typically [6]. A proper energy reduction potentially prolonged the DMS system in terms of stability and lifetime [3]. This enables the Emergency Response Team to save more human life as much as possible [2].

Consequently, energy-saving becomes essential when sensor nodes are powered by their restricted battery. Sensors spread over a large area or in a harsh or hostile area such as volcanos or even deep-sea when battery power is depleted. It could be difficult or uncomfortable to exchange or recharge the battery [7].

The leading cause of sensor node's energy waste is the radio system [4]. For that reason, several concepts and strategies has been emphasized on power saving in reducing the data sending like scheduling, aggregation, routing and clustering [8]. Generally, when selecting different types of wireless network technologies linking with DMS, a few considerations we need to take into account on the particular application like power consumption and maximum distance range [9].

Overall, this research work greatly benefits the community in terms of minimizing human life as much as possible that contributes to DMS, which is listed below.

- Multichannel
- Network Establishing and Channel Formation
- Interface

Therefore, the principles and structure of this research work are to identify the method proposed in DMS with modifying VASNET on IoT technologies that determine by using energy consumption and packet loss. This paper was structured as follows: the main challenges on VASNET and IoT are discussed in Section II, related works in Section III, proposed framework in Section IV, performance evaluation and method in Section V, result and discussion in Section VI and conclusion in Section VII.

II. Challenges on VASNET and IoT

There are challenges that cannot be avoided in any wireless network. The primary challenges and limitations in which it could affect the performance in the wireless network are discussed below [3], [10].

1) Security
   - Varies method has their strengths and weaknesses and none of them provide the best solution on it. For instance, vehicle-to-vehicle (V2V) focuses on several attributes including authenticity, authority, integrity with confidentiality. Different V2V applications such as e-health systems and smart metering may have various privacy requirements which need to be taken into account during the initial stage of system design [11].
2) Mobility
   - High mobility of VASNET for vehicles to move randomly compared to other wireless network infrastructures. Which may contribute a redundant data collected to nearby RSS (Road Side Station) or BS (Base Station).
3) Power limitation
   - In VASNET, power constraint is one of the most important challenges in which it shadowed all other aspects like routing, fusion, and the massive battery carried by the device. For instance, car batteries.
4) Devices challenges
   - In the same network, it may be equipped with various types of protocol capabilities on different sensors or devices. For instance, a vehicle system is a critical challenge especially in a tracking system as the node is movable [6].
5) Big Data
   - A huge amount of data may produce conflicting meanings(vagueness), which requires checking for quality and value. Multiple deployments on similar sensors increase data accuracy. However, it could experience extra noise data [12].
6) Other Challenges
   - Several challenges also impact the design of wireless network sensors. For instance, a group of sensor nodes moves into a particular portable robot or various automobiles. It would result in any sensor network topology constantly being altered in which request of changes is repetitive. Some needs for MAC (Media Access Control) for density modification, routing on neighbour lists modification with data gathering.

III. Related Works

The main objective of this review is to thoroughly examine the published works of literature that extend the sensor network regardless of the existing DMS system with VASNET modification in various applications and IoT. It shows a relationship in any sensor work in multiple methods related to this research field. There is limited research involving different types of wireless technologies to be executed in any state-of-art system, which will become very demanding in the future research area.

Below is the discussion of previous works done in any technique, algorithm and method related to the energy consumption in the IoT network field and wireless network.

Energy Harvesting system is introduced in the works of the author [3], in which a clustering algorithm was applied on sensor nodes to form a cluster with Cluster Head (CH). This CH was equipped with an external energy source to supply power to prolong the CH in terms of network efficiency. CH transmit and receive a signal link with BS to enable network communication between the sensor nodes in a particular area. However, this method was restricted when the node movement was dynamic and randomly caused frequent re-clustering and affected the energy supply to be depleted to a certain level.

Another well-known clustering base protocol is Low-Energy Adaptive Clustering Hierarchy (LEACH) in author work [13], has been discussed. In this LEACH, the sensor nodes were organised into the cluster, with each cluster are randomly selected. The weak point of this LEACH is that CH was experienced less residual energy on selected CH, which would result in inactive mode quickly. As such, the whole cluster would fall into a non-functional mode and reduce the effectiveness of this LEACH clustering protocol.

To reduce energy consumption on wireless networking for IoT, the author [4] proposed a data reduction method that works on Gateway of network level. It operates on a group of data received by identifying and removing the redundant data set that undergoes a classification process. The author suggested a clustering candidate set to verify a similarity among the members. The data sets after clustering candidate sets were able to transmit through Gateway with minimum energy consumption. To some extent, this research work may have risks when the same valuable data sets have been removed and time-consuming while facing many sensor nodes.

The compression algorithm applied from one data form of sensor node was installed in a wireless sensor network in an underground tunnel in terms of spatial-temporal data has been explored by the author [14]. The proposed algorithm effectively operates on temporal and spatial characteristics for the sensor's data. The data recovery method was nearly approximate to an initial data node. This algorithm served a high complexity for data compression and, therefore, was difficult to be considered on the limited resources node practice in IoT networks.

The idea of the Prefix-Frequency Filtering (PFF) technique was proposed by the author [15]. This technique is divided into two phases; the sensor phase to utilize the local data processing and the aggregate stage for PFF with Jaccord Similarity mechanism that can consolidate data similar from nearby sensor nodes. However, this technique was not competitive in reducing redundant data before broadcasting to the BS.

Implementation of decentralized hierarchical clustering is proposed to avoid the redundant control message transmitted from sensor nodes to BS done by the author in [10]. The formation of sensor nodes clusters with a criterion of intra-cluster among sensor nodes and CH being selected according to the shortest distance between sensor nodes and BS. CH was revalidated each time on sensor nodes remaining energy. Thus, it identified energy depletion and overloading on any particular sensor nodes. But when operating in multiple criteria, this algorithm works in performance-less that includes heavy computational complexity in the data transferring process.

The author introduced an Adaptive Lossless Data Compression (ALDC) algorithm in [16] for wireless sensor networks. It incorporates several coding to achieve lossless compression alternatively. This method permits the adjustment of compression dynamically to the changeable source. It comprises blocks, and each block implements the optimal compression method. However, this method increases the time complexity and is not suitable to apply on the gateway.

IV. Proposed Framework

In order to justify the reason to conduct this research work. The current VASNET and IoT framework underwent a study to identify the problem and limitations. RSU (Road Side Unit) linking with a gateway for VASNET networking is a disadvantage during disaster or catastrophe occur. RSU may partially or fully destroy during the impact of the disaster, especially by tsunamis and landslides. Communication breakdown in the affected area can cause survivors trapped inside the vehicle to face difficulty to be rescued by ERT members. High node density of vehicles in one area and shorten communication range can be a reason or problem for the existing VASNET framework. Packet congestion or high traffic on VASNET degrade the performance of data transmission and retrieve data that might be experienced by ERT members. On the other hand for the IoT framework. It will be costly to equip a device which able to sustain an extreme situation in high temperature and high-pressure environment, regardless of communication range or protocol. High maintenance of IoT networking is one of the main reasons, why IoT is not suitable to be implemented on existing DMS. It involves a large area, for instance, the metropolitan city which causes a million of financial support that not all the country can handle like the third-world country. As a result of this, modification of VASNET is a must to overcome the short-distance communication coverage and reduce network congestion by using IoT technology. IoT can suit this VASNET to implement point-to-point network connection to cost down current IoT infrastructure. As such, this research aims to combine and modify both VASNET and IoT to become more stable and reliable to apply to DMS systems. Consequently, the interface is introduced in this research study, which is a medium to link different protocols on VASNET and IoT through varying artificial intelligent devices like smartphones and smart switches through the algorithm proposed.

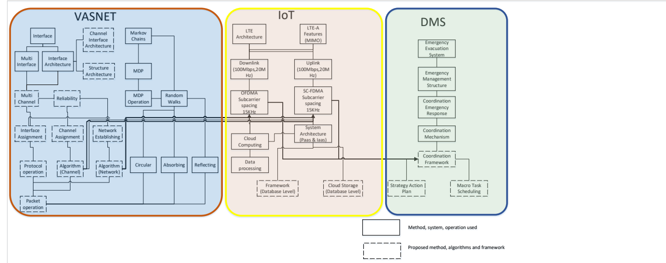

Fig. 1. Proposed Hybrid Framework.

The most complex and challenging part is integrating two different network topologies into a DMS system that enhances performance in terms of stability and reliability. The interface becomes the key that enables VASNET and IoT to communicate simultaneously. Thus, execution of both wireless networking potentially generates an unwanted energy dissipation which causes degradation of hybrid network performance. To solve this problem, the transmission medium and modulation module becomes crucial as the purpose is to reduce energy consumption as minimum as possible. Therefore, the proposed framework depicted in Fig. 1 illustrated this hybrid model implemented on the DMS system.

It can be observed from the diagram in Fig. 1, existing VASNET has to be modified by introducing an interface with Channel Assignment and Network Establishing algorithms. Those algorithms have been implemented by applying Markov Chains and LTE with LTE-A to configure a nearby node in a post-disaster scenario. Markov Chains potentially locate the latest state of survivor that depends on the existing state especially in heavy floods and volcano disasters, making the movement of humans trapped in random mode in any emergency. Therefore, Markov Chains implementation can connect and link all nodes (Survivor) in a certain disaster area. Furthermore, LTE and LTE-A are suggested as a communication protocols with less latency and coverage area up to 5km. With this, it enables the Emergency Respond Team (ERT) to connect with survivors without any barriers in terms of communication. This algorithm plays an important role to integrate with IoT structure and the idea of channel interface and structure architecture on interface able to link both VASNET and IoT together. The objective of this interface is designed for a multichannel or multimode approach. It permits the system to detect and identify as many victim locations (node) in the short and medium range.

This interface connects the VASNET and IoT architecture on particular Long Term Evolution (LTE) for Downlink and Uplink medium to optimize the communication flow. The LTE architecture in IoT can handle multi-node that result in shortened latencies in terms of signal control [17]. Moreover, IoT network architecture is upgraded to add in suggested Database in Cloud environment to the IoT architecture due with Platform as a Service (PaaS) and Infrastructure as a Service (IaaS) level. The advantage of IoT in the Multi-node approach is that it works on OFDMA in Downlink and SC-FDMA on Uplink, which is the main critical point on Downlink. It could contribute more energy when ERT (Emergency Response Team) communicates with various victims to locate the victim more accurately. OFDMA has the characteristics of separating the data into several narrowband subcarriers to improve the bandwidth [17] during emergency periods.

The hybrid architecture would be connected to existing DMS to enhance the DMS performance in which the DMS system should equip with the coordination framework. This coordination framework is explored to suit the hybrid framework that can receive valuable data or information in a real-time situation during an emergency. Strategy Action Plan and Macro Task Scheduling is the idea to optimum the DMS system performance link with this hybrid framework, and capable to strategy the rescue plan effectively to rescue innocent people during disaster or catastrophe occurs.

V. Performance Evaluation Method

To examine the performance of a hybrid framework in terms of stability and reliability. The energy consumption on BS in this hybrid framework will be determined as this is the most essential and significant part. As a result, the parameter of energy consumption and packet loss at BS will undergo testing, and all the evaluation methods or steps are elaborated on below.

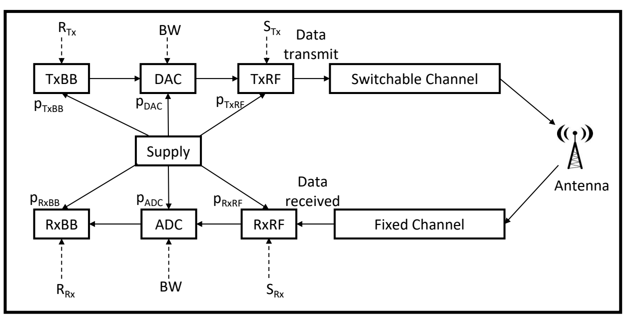

Fig. 2. The Energy Consumption Model.

Fig. 2 depicts the power consumption model node consisting of power level (s), transmit T_x and receiver R_x, Base Band (BB), Bandwidth (BW) and radio frequency T_x and R_x. Where P is classified as total power consumption in idle and connected mode, R_{xRF} and T_{xRF} in RF part on R_x and T_x chains are consumption on each other. R_{xBB} and T_{xBB} are consumed on BB parts, and 2CW is increased while two codewords (CW) are in the downlink. For parameters on P_{Rx}, P_{Tx} and P_{Rx+Tx} are on idle, receive, transmit, and use 2CW. The R_x and T_x power level is considered S and R_x, and T_xx is the R data rate individually.

Each respective node was set to 50mW with low power consumption to obey LTE-A characteristics. Each packet converted was divided into power settings concerning the base station to gather each node's energy consumption.

$$\sum_{i=1}^{n} P_T = m_{idle(i\to n)} P_{idle(i\to n)} + \overline{m_{idle(i\to n)}}\{P_{con} + m_{Tx} \cdot m_{Rx} \cdot P_{Tx+Rx} + m_{Rx}[P_{Rx} + P_{RxRF}(SR_x) + P_{RxBB}(R_{Rx}) + m_{2cw} \cdot P_{2cw}] \cdot m_{Tx}[P_{Tx} + P_{TxRF} + P_{TxBB}R_{Tx}]\}w \quad (1)$$

$$\sum_{i=1}^{n} P_T = \frac{\sum_{i=1}^{n} Joule}{Seconds} \quad (2)$$

$$\sum_{i=1}^{n} Joule = \sum_{i=1}^{n} P_T \times Second(s) \quad (3)$$

$$\sum_{i=1}^{n} EnergyConsumption(Average) = \frac{\sum_{i=1}^{n} Joule}{Byte} = \frac{\sum_{i=1}^{n}(P_t \times Second(s))}{Byte} \quad (4)$$

We apply LTE on the same hybrid framework to compare the LTE-A energy consumption.

VI. Result and Discussion

We consider downlink as principles measurement for energy consumption as it is the most significant to contribute energy consumed on network access that can evaluate energy efficiency [18]. Furthermore, low and high data rates have also been used to determine the proposed framework in parameter CQI (Channel Quality Indication), which is CQI=2 (low) and CQI =7 (high). Below is the tabular form and graphical form of this experiment result obtained.

TABLE I. Energy Consumption for Low Data Rate on 500m for 15s

Node	LTE	LTE-A
20	25.00	10.00
40	64.00	60.00
60	75.00	71.43
80	80.00	77.78
100	83.33	79.82

TABLE II. Energy Consumption for High Data Rate on 500m for 15s

Node	LTE	LTE-A
20	50.00	33.33
40	75.00	66.67
60	85.00	80.00
80	90.00	87.00
100	95.00	92.00

Table I and II show the result for low data rate (CQI=2) and high data rate (CQI=7) on 500m and 15s.

Fig. 3 shows energy consumption for low data rate (CQI=2) and high data rate (CQI=7) for LTE and LTE-A with 500m range.

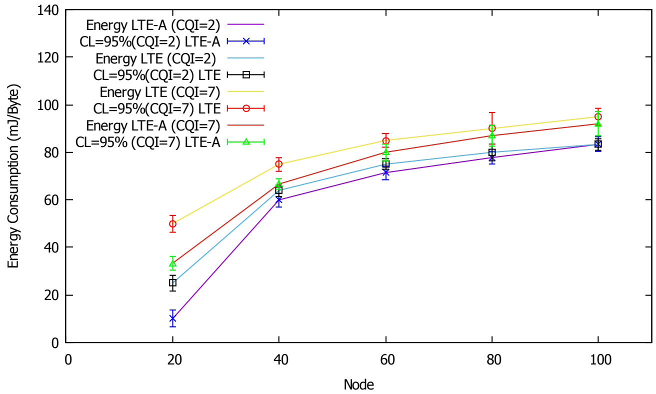

Fig. 3. Energy Consumption Result for 500m on 15s for High Data Rate (CQI=7)and Low Data Rate (CQI=2).

As presented in Fig. 3, the most effective increasing rate was at node 40 group that was showing high data rate for LTE contributes 25 (mJ/Byte), LTE-A 33.34 (mJ/Byte). LTE contributes 39 (mJ/Byte) for low data rates and LTE-A 50 (mJ/Byte). On node 40 onward, all LTE and LTE-A gradually increase, reaching LTE as 20 (mJ/Byte) for a high data rate, LTE-A 25.33 (mJ/Byte), respectively. LTE was 19.33 (mJ/Byte) and LTE-A for 19.82 (mJ/Byte) on low data rate. This is because network formation and channel establishment executed at an initial stage establish a connection among central stations with all the nodes nearby. Besides that, the high mobility of nodes could contribute to the amount of energy consumption as packet loss happens concurrently. Retransmission of packet needs more energy, and it keeps increasing with the condition of the number of nodes in increasing trend and various pattern change also increase simultaneously. Consequently, the channel quality reflected the amount of energy dissipation and consumed more on high data rate compared to the low data rate.

TABLE III. Packet Loss for Low Data Rate on 300m

Node	LTE	LTE-A
20	8.87E-03	8.74E-03
40	9.58E-03	9.50E-03
60	9.88E-03	9.80E-03
80	9.89E-03	9.85E-03
100	9.96E-03	9.90E-03

TABLE IV. Packet Loss for High Data Rate on 300m

Node	LTE	LTE-A
20	8.87E-03	8.87E-03
40	9.42E-03	9.42E-03
60	9.90E-03	9.73E-03
80	1.00E-02	9.83E-03
100	1.02E-02	9.94E-03

Table III and IV show the experiment results for packet loss for LTE and LTE-A for high data rate (CQI=7) and low data rate (CQI=2).

Fig. 4 and 5 show the tremendous packet loss increase fell into node 40 group for low data rate on LTE 11.39% and LTE-A 8.0%. On the other hand, the high data rate presented 14.80% for LTE and 11.97% for LTE-A. Generally, LTE-A improved compared to LTE by about 19.12% for the 300m range.

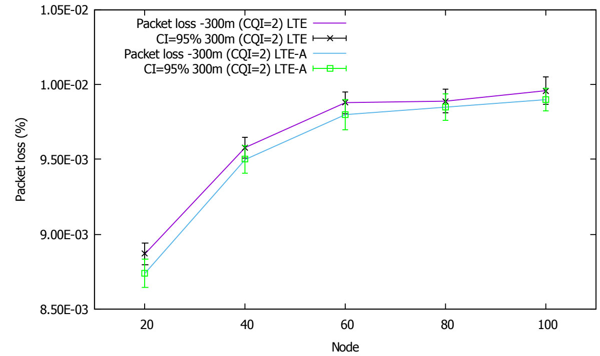

Fig. 4. LTE-A and LTE Packet Loss for 300m (CQI=2).

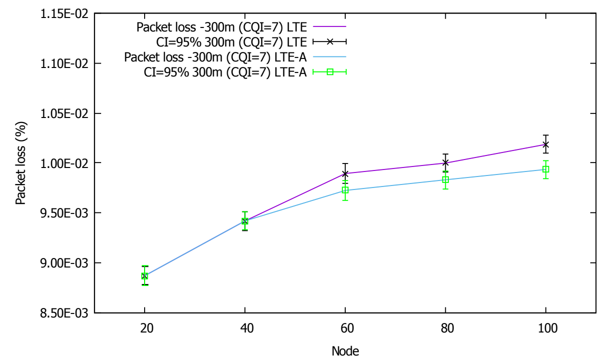

Fig. 5. LTE-A and LTE Packet Loss for 300m (CQI=7).

The packet loss rate gradually increased for both LTE and LTE-A due to the random movement for the 300m range. High-speed mobility can cause the packet transmitted to lose its path because the transition node or relay is out of the network coverage as the central station has to reschedule and retransmit to any particular destination node. Therefore, the existing network has to reform with the neighbour's node to create a new channel and coverage. Instead, a high data rate (CQI=7) experienced a massive amount of energy needed to broadcast the packet in the node-by-node primary. It will produce a lot of energy consumption directly to the network coverage.

VII. Conclusion

In this research work, the modification of VASNET integrated with IoT on DMS was successfully evaluated using low and high data rates. It was able to investigate the effect of stability and reliability by parameters applied to the proposed framework by using energy consumption with packet loss rate.

The result presented a high data rate showing significant influence with more energy on LTE-A as 25.33 (mJ/Byte) compared to LTE 20 (mJ/Byte). At low data rate, LTE-A also gives ultimate contribution by 19.82 (mJ/Byte) higher than LTE with 19.33 (mJ/Byte). The works of packet loss determined that LTE contributed 11.39% higher than LTE-A on 8.0% for low data rate, and high data rate, LTE is also higher than LTE-A with 14.80% and 11.97%, respectively. Overall, it can be concluded that a high with low data rate on energy consumption parameter, LTE-A significantly impacts proposed framework performance. However, LTE on high and low data rate was higher in terms of packet loss parameter.

Therefore, for further work, 5G is suggested to evaluate the proposed framework in energy consumption measurement and packet loss.

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