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Sensor Routing Protocol with Optimized Delay and Overheads in Mobile based WSN

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***Abstract*: Recent years have witnessed the emergence of mobile wireless sensor networks as an interesting field of research in contrast to their more advanced static counterpart. Although mobility in MWSNs relaxes issues concerning connectivity and coverage, many more challenges still need to be addressed. Routing and localization among these, remain at focal point. In this paper, a robust and relatively new protocol which exploits the sensor's mobility to deal with routing problems in mobile sensor networks is discussed. The protocol's algorithm is based on utilizing the location information of sensor nodes which improves the performance when compared to mobile ad-hoc network protocols like ad-hoc on-demand distance vector (AODV). The use of blind forwarding technique creates packet redundancy, thus increasing the reliability of the protocol. This improves energy utilization and reduces hardware cost. Routing overhead, end-to-end delay are used for protocol evaluation. The simulation results show better potential of LASeR in mobile environments than other conventional protocols.**

***Keywords*:** dynamic source routing, Quality of Service, Wireless Sensor Networks, Internet of things, ad-hoc on-demand distance vector.

I. Introduction

In recent years, Internet of Things (IoT) has emerged as a new paradigm which com-bines the human's needs and technological progress [26,28]. There are a vast set of applications ranging from area monitoring, health-care monitoring, environment sensing, industrial monitoring, rescue operations, logistics and many more in which communication and interaction with the environment are imperative [1,12]. This heavily depends on the reliability of Wireless Sensor Networks (WSNs). Mobiles WSNs is a fast emerging field of research in contrast to the entrenched static WSNs [22]. Theoretically, although being more versatile and adaptive to changing topology, practically their usability is limited due to challenges in packet routing from source(s) to destination [33]. Protocols designed for mobile WSNs are generally multihop or hierarchical which are prone to large overheads in case of high speeds. Also, location information is utilized from GPS-enabled nodes rendering it less cost and energy efficient. One proposed solution that addresses the above issues is the Location Aware Sensing Routing (LASeR) Protocol implemented along with distributed cooperative localization [4].

1.1 Thematic Concepts of Mobile WSNs

A mobile wireless sensor network is a wireless network that consists of resource constrained mobile sensor nodes deployed in a designated area serving various application purposes [13]. Witnessing the evolution of static wireless sensor networks over its advancement in resource efficiency, communication protocols hardware design and many aspects over the past decade, recent research is now mainly focused on the mobile WSNs owing to their many advantages over static WSNs.

1.1.1 Advantages of Mobile WSNs

Deployment of sensor nodes are often application dependent. For optimal deployment, sensor nodes collect and process data and are again redeployed. This is generally infeasible for static WSNs. It is shown in [10] and [6] that mobility improves the versatility, utility, coverage and lifetime of the sensor network. It also increases the channel capacity by reducing the number of hops and creating multiple communication paths. Often networks are centralized, incurring significant overhead to the base station. Mobile WSNs usually have mobile base stations which minimize the hops by traversing the network [2]. In static WSNs, nodes deployed at initial positions do not update their locations, while in mobile WSNs, locations are updated continuously which trades off with additional time and energy.

1.1.2 Rooting in mobile WSN

Routing in mobile WSNs is very challenging as compared to the state-of-art routing in static WSNs due to inherent challenges like mobility, limited power, bandwidth and time.

It also needs to address other challenges like data aggregation, hardware limitation, changing topology and scalability. The network design objectives mainly consist of following parametric assumptions.

- *Small node size*: The bulkiness of the nodes interferes with its usability and mobility. The size of the nodes must be small for easier deployment in harsh environments [3].
- *Low cost*: As the number of nodes expands, cost becomes a limiting factor in large networks where cheaper and efficient technology is more favoured.
- *Low power consumption*: Low power consumption increases the lifetime of the sensor node, thereby, prolonging the network.
- *Scalability*: The performance of the designed protocol must be consistent irrespective of the network size.
- *Reliability*: The designed protocol must provide error detection and correction mechanisms for reliable communication.
- *Self-configurable*: The nodes deployed in the network autonomously must have the ability to reconfigure themselves in case of change in environmental conditions or node failure.
- *Channel utilization*: Bandwidth usage must be efficient for better channel utilization.
- *Fault tolerance*: Overall network must not be affected by the failure of one or more sensor nodes.
- *Quality of Service (QoS):* Each application requires a bounded latency in delivery and packet loss. The designed protocol must consider the specifications.
- *Security*: For reliable and authentic accessibility, the designed protocol must provide security against foreign invasions.

1.1.3 *Localization*

Protocols for mobile WSNs strongly rely on the real-time location information which consumes much sufficient power. Presently, GPS is a widely used method for localization, where mobile nodes compute their locations using satellite sent signal information data containing light time and orbital position [8,32]. Though accurate within 10 meters, they work under the line of sight and are relatively power-consuming and expensive. Algorithms designed for localization are mainly accepted by the noisy ranging information.

1.2 Application of MWSNs with localization and tracking

Service Industry: Many tasks performed by robots like basic healthcare in hospitals, maintenance, security and many more require position estimation for serving its users.

Fig.1 Mobile network applications in wireless modes [5].

Housekeeping: Automated vacuum cleaners uses feedback from motion and optical sensors to create the map of the room. While, self-docking stations self-recharge their batteries [7, 25, 31]. Wildlife tracking: Many types of research in zoology rely on tracking animal activities and their positions without disturbing their natural activities. Fig. 1 represents various applications meeting the cut edge of recent technology in mobile based wireless sensor network.

Pollution monitoring: Vehicles mounted by pollutants detection sensor nodes records the pollution concentration and send to the nearest base station stamped with location and time. Kumar et al.(2017) introduced a deep network architecture which can be used for pollution monitoring using machine learning [19].

Weapon classification and shooter detection: Sensors attached on wearables uses the properties of the acoustic signal, TDOA and the shock waves generated by the projectile to classify the weapon and estimate the enemy position. Autonomous deployment: Sensor networks are deployed to aid the surveillance, repair and control field operations.

The remaining text of this paper is organized with the constructs: section 2 presents detail of related work with architecture, routing and localization of WSN network [18, 27]. In section 3 mathematical model for the experimental set up is presented and later in section 4, simulation and results are discussed. At last, section 5 concludes the overall summary and future directions to develop a better mobile WSN architecture.

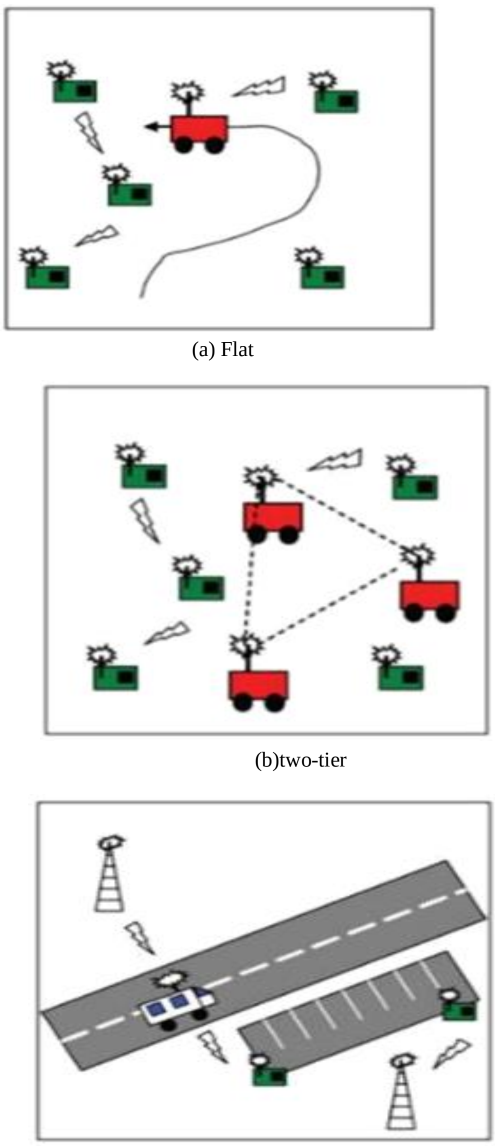
II. Related work

The related on mobile wireless sensor network is categorized on the basis of its architecture and routing strategies.

2.1 Mobile WSN Architectures

The taxonomy of mobile WSNs [1] is largely influenced by the traditional static WSNs and MANETs. The hierarchical (tier) architecture of mobile WSNs can be categorized under:
Planar sensor network: The network architecture comprises of several mobile or stationary homogeneous nodes that communicate in a multi-hop ad-hoc manner. Here as the network becomes large, there is an asymptotic fall in performance as pictured in figure 2.

Two-tier sensor network: The network overlay consists of both mobile and stationary nodes. Here, the mobile nodes are either utilized as data mules or as an upper overlay network for data communication. The topology of the upper overlay is kept ephemeral to ensure the connectivity of the network. Mobile nodes have greater processing, computing, caching and transmitting capacity. However, as the density of mobile nodes becomes sparse, performance degrades.



(a) Flat

(b)two-tier

(c) Three-tier

Fig. 2. Flat (a), two-tier (middle) and 3-tier Mobile Wireless Sensor Network (MWSN) (right) architectures [1].

Three-tier sensor network: The network architecture combines the advantages of its both predecessor architectures. Here, the agent is reversed as the stationary nodes transmit to the mobile nodes which further transmits to the access points, reducing power consumption. It performs as a data gathering network increasing overall efficiency.

The sensor nodes also serve many roles in the network [5,20]. They can either be mobile actuated, mobile-embedded, data mules or access points.

2.2 Routing in Mobile WSNs

From the observations carried out from fig. 2, the mobile ad hoc networks (MANET) follow the shape the routing infrastructure of the mobile WSNs. In particular consideration, host mobility leads many operations frequently such as alarm signaling, routing and paging any specific host [5,15,24]. The overlapping and contention of radio signal in geographical area create a serious problem referred as broadcasting storm problem in the sensor network domain. By deep analysis and simulations Chen et al. [11] refereed it a very serious and proposed several effective schemes to reduce redundant broadcastings to alleviate this problem. The routing protocols of MANETs are categorized as:

2.2.1 *Topology-based routing protocols*

In topology-based protocols, the packet forwarding is done using the link information between the nodes in the network. They are further sub-divided into:

Pro-active routing protocols: The pro-active protocols use the classical state-of-art route path discovery for routing. The varying topology is dealt by continuous evaluations of new and existent routes [34]. This causes large computational complexity, bandwidth consumption and overhead. Examples include destination sequenced distance vector (DSDV) and optimized Link state routing (OLSR).

Reactive routing protocols: The reactive protocols discover the route on demand and eliminate the not-required continuous path updates. The path is located by flooding the network by the source node. This causes delay and constrain on bandwidth. Examples include dynamic source routing (DSR) and ad-hoc on-demand distance vector (AODV).

Hybrid routing protocols: Combining the advantages of both prior protocols, hybrid protocols increase the efficiency of network by limiting the route maintenance. It introduces the zone concept and routes data by taking pro-active approach. The most popular examples include intrazone routing protocol (IARP) and interzone routing protocol (IERP).

2.2.2 *Position-based routing protocols*

In position-based protocols, routing is optimized by utilizing

the location information of the nodes known through beacons. The packet forwarding can be performed using:
Restricted directional flooding: In restricted directional flooding, multiple duplicate packets are transmitted to all the nearest neighbours present in the direction of the receiver node. One example is DREAM protocol [36].

Greedy packet forwarding: In greedy packet forwarding, routing is done in the direction of the receiver node to minimize the path travelled by the packets. Routing strategies which are used include compass routing and perimeter. One example is greedy perimeter stateless routing protocol (GPSR).

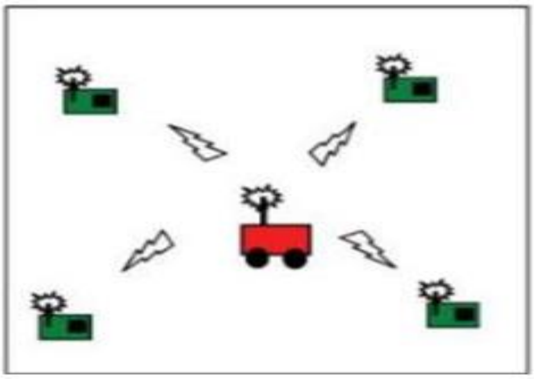
Mobile WSNs utilize various adaptations of MANETs. Routing protocols like opportunistic routing and AODV with pre-emptive self-repair uses topology-based MANETs. Owing to the dynamic nature of network, position-based protocols achieved higher performance in comparison to topology-based protocols [16, 29, 30]. LASeR protocol conform to GPSR and utilize blind forwarding to increase the performance.

2.3 Localization in mobile WSNs

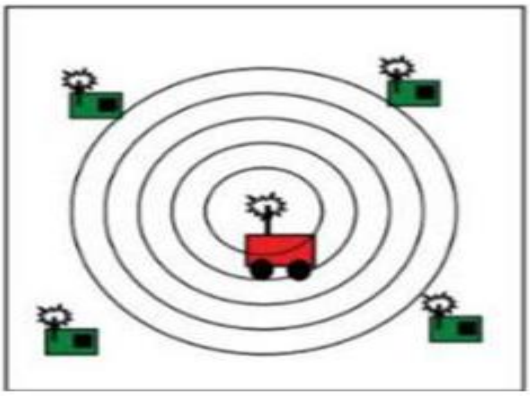
Mobile WSN localization typically undergoes three phases coordination, measurement and localization phases which are presented and picturized in fig. 3.

Coordination phase: Before the beginning of transmission, coordination between the participating nodes is necessary to avoid delays in the network. It includes clock and frame synchronization. The main methods used are elapsed time on arrival (ETA) and reference broad synchronization (RBS).

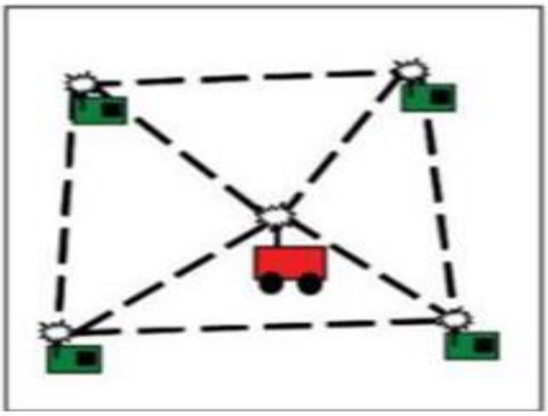
Measurement phase: In measurement phase, the anchor nodes begin the transmission. Signals are processed on all regular nodes. The signal module required by the nodes varies with application, deployed environment and hardware. They can either be radio frequency based, acoustic, spotlight or infrared based. After signal measurement, the information on proximity is estimated by several methods, most widely used among them are time-of-arrival (TOA) and received signal strength (RSS). In TOA, signal time is measured between the arrived packet and the transmitted packet. It is mainly used for acoustic signals [23]. RSS uses free-space signal strength model to profile the signals. It is generally used for radio signals. Other methods include time-difference-of arrival (TDOA), Doppler shifts and angle-of-arrival (AOA).



(a) Coordination



(b) Measurement



(c) Localization

Fig. 3. In the sequential localization phase: Coordination (a), measurement (b) and localization (c) [9].

Localization phase: In localization phase the approximate positions are calculated using the data from the former step. Estimation methods employed varies with the type of data received and noise filtration. It mainly includes cellular proximity, dead reckoning, angulation and literation. Sequential Bayesian estimation (SPE) and maximum likelihood estimation (MLE) techniques are used when the system is under-defined and noisy [9, 13,14]

Localization algorithms can be categorized as centralized and distributed. Centralized algorithms follow asymmetric architecture and have good accuracy, load and precision at the cost of failure risk, latency, high power consumption and scalability. Distributed algorithm, on the other hand, follow symmetric architecture and reduces computational time, latency at the cost of slight inaccuracy. Localization on LASeR is done using fully distributed cooperative localization.

III. PROPOSED MATHEMATICAL MODEL

In general, the estimated cost of end-to-end delay is computed by summing up the transmission time, propagation time, queuing time, and processing delay in the signal propagation. Conceptually, this can be represented by equation (1) and mathematically computed using equation (2) which is known as average delay equation.

$$Average_{EndToEnd}Delay = \frac{Arrivaltimeofpackets - Sendtimeofpacketes}{Totalno.ofcollections} \quad (1)$$

$$D_{av} = \frac{h.T_s.(2 - \mu T_s)}{2.(1 - \mu T_s)} \quad (2)$$

Where μ is arrival rate of packets to each node as given in equation (3)

$$\mu = \frac{f_p.(n-1)}{N_n^2} \quad (3)$$

Where f_p denotes rate of packets generated at each node, and N_n is one-loop adjacent node as computed accordig to equation-(4)

$$N_n = \frac{\pi.r^2}{L^2}.(n-1) \quad (4)$$

Where n denotes the number of networks and L is length of network. Again reffering equation (2) T_s is service time as computed in equation (5)

$$T_s = (n-1).\left(\frac{L_p}{R_b}\right) \quad (5)$$

Where L_p is packet lost time and R_b bit rate in transmission. The overhead in network is defined as the aggregate number of bits sent devided by number of correctly delivered bits as represented in equation (6).

$$OH = \frac{B_{tx}}{L_{data}.N_p.PDR} \quad (6)$$

Where B_{tx} is total number of bits sent which are computed accordingly eqaution (7)

$$B_{tx} = N_f.L_p.N_p \quad (7)$$

Where N_p the number of packets is generated, Again PDR referring equation (6) is Packet Delivery Ratio which is basically ratio of total number of bits received to total bits sent from source towards the sink. Mathematically, equation (8) can be used to compute PDR as follows-

$$PDR = 1 - \left(\frac{D_{av}.p.v_{max}.h}{4.r}\right) \quad (8)$$

The above equation shows that PDR ratio is affected by average delay D_{av}, maximum speed of transmission, number of hops (h) and radius of transmission.

IV SIMULATION AND RESULT DISCUSSION

4.1 Environment specifications

We performed the simulations in NS2 modeler. 25 nodes were randomly deployed in a grid map of size 600 by 600 meters. The minimum speed of nodes is set to zero and the maximal speed is varied for different simulations. The use of a small area network reduces the chance of a node being non-functional for a long interval. Assuming that the nodes communicate well in their transmission range, which implies that there is no error due to noise or fading effects. Packet generation rate is set at 1 packet per second. The transmission range and data rate are modelled at 250 m and 250 kbps respectively. Similarly, simulation results are prepared for AODV protocol. These results are then compared with the results of LASeR protocol. Results are compared for packet delivery ratio, overhead, throughput, and end-to-end delay.

4.2 Mobility specifications

This section shows the comparison results of AODV and LASeR protocol obtained with varying maximum speed of [25,40,60,80,100] m/s. All other parameters are kept constant [16,17] The graphs of each parameter described in section 3.2 is obtained for both the protocols with varying speed of nodes for comparison purposes. The corresponding results are shown in fig 4 to fig 5.

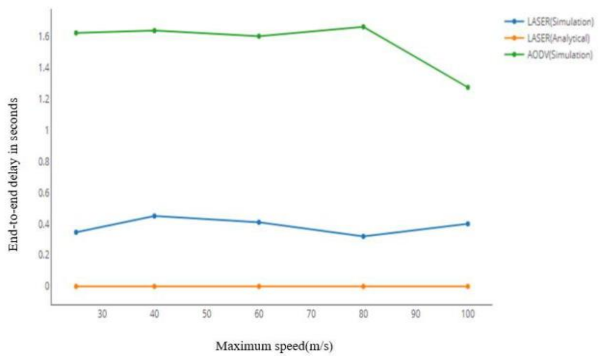


Fig. 4. End-to-end delay against maximum speed.

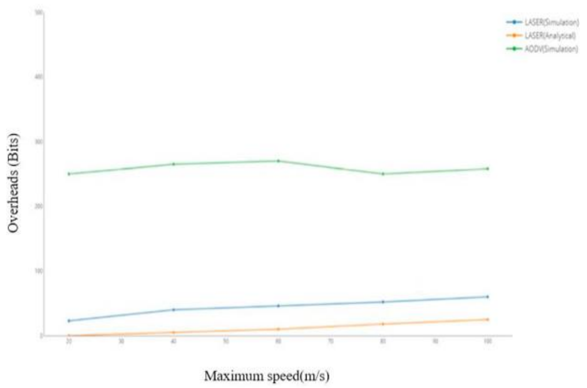


Fig. 5. Overhead evaluation against maximum speed.

V. Conclusions and future recommendations

The most common problem broadcast storm problem creates the several serious issues such as serious redundancy, contention, and collision etc. Alternatively, the straightforward broadcasting of signal by flooding is usually is not very cost-effective. In this paper we have implanted LASeR protocol. The location information of nodes is estimated using the known locations of anchor nodes. The use of blind forwarding, creates route diversity thus making it ideal to deal with frequent topological changes. The robustness of the protocol is verified by simulation results. The results for this protocol show high level of performance over the conventional protocol AODV. High packet delivery ratio and low average end-to-end delay makes the protocol reliable and fast. These characteristics make LASeR well suited for a lot of applications. The research work presented in this paper concludes with the combined implementation of LASeR protocols will optimizes the overheads and end-to-end delay. From the current state of the work, we recommend the protocols made viable by using position estimation for localization.

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