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Routing Protocols of Wireless Sensor Networks in Smart Cities

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***Abstract*—**
The investigation on smart cities using WSN-wireless sensor networks seems to be able to benefit from the development of the Internet of Things (IoT) since both of the technologies' goals were comparable. Simultaneously with them, research on managing mobile crowd sensing (MCS) and WSN innovations encounter fresh potential and difficulties, particularly when implemented in a sizable context like a smart city setting. However, fresh approaches are being put out to handle current WSN and resource utilization challenges. To integrate the two technologies of sensing WSN and MCS, this study suggests a hybrid routing protocol depending on the RPL protocol. The idea is to assist the fixed nodes of WSN to improve performance by appropriately using MCS nodes. A fixed WSN has been used to evaluate the suggested protocol to examine the effect of integration on WSN functionality. When compared to RPL without MCS integration, the proposed findings show a good improvement in packet distribution proportion of 17% higher, end-to-end latency of 50% lesser, and energy usage of 25% less. Hence this research believes that the hybrid-RPL protocol may be effective for sensing and data acquisition, particularly in urban and smart city situations.

Keywords: *Smart Cities, Internet of Things, Wireless Sensor Networks, Mobile Crowd Sensing, and Routing Protocols.*

I. INTRODUCTION

Today, the concept of a "smart city" is associated with different terminology and interpretations [1]. The concept was typically created to describe the developments in urban technologies that resulted from systems interconnection. The development of the Internet of things (IoT) and information communication technology (ICT) is thought to be the primary force behind the development of smart cities [2]. By 2050, it is predicted that 68% of the universe's population might reside in urban regions, according to statistics provided by the UN [3].

Technically, IoTs and smart cities are still in their development in numerous cities. There aren't many IoTs that are entirely capable of achieving the goal of smart cities [4]. For developing technologies, the majority of study projects deal with IoT platforms, concepts, models, and use scenarios [5]. In smart cities, sensing is the foundation of the system. To assure optimum material usage, functional detectors with a widely dispersed spectrum and good communication must be used. A substantial variety of sensors that are linked to one another and communication of information with one another are necessary for such a method to be successful. A communication network and a system for gathering and analyzing data must be developed in response to this [6]. Hence, different strategies might be taken into account for networks like the IoTs, and Wireless Sensor Networks (WSNs).

The adoption of this system to evaluate urban living standards is now possible due to advances in WSN sensing and ICT [7]. As a result of their small size and connectivity features, sensing nodes can indeed be placed in locations that are difficult for people to access. WSNs are becoming increasingly more affordable, enabling their installation to monitor and manage virtually any region even in tough situations, demonstrating their critical role in influencing the IoT framework. For example, humidity and room temperature in residential or commercial premises can be efficiently monitored and managed by WSNs to create a suitable atmosphere for both residing and working. Sensors are placed across the entire city for surveillance and monitoring in a Smart City scenario [8]. Common applications comprise electronic toll-collecting tools, highway data gathering, automated recognition of number plates, management of traffic, surveillance of traffic signals, and structural health management [9].

Mobile crowd sensing (MCS) represents a novel sensing technology in smart cities that has recently gained popularity in the scientific and business communities. It makes use of the sensing and networking devices included in the newest smartphones [10]. Devices can create a network topology utilizing ad hoc network communication due to the benefits of cellular-installed networking interfaces like Wi-Fi & Bluetooth. This enables data transmission and communication between objects without the requirement for system-oriented networks, like 4G or cellar networks [11].

WSN monitoring systems frequently function in a resource-constrained environment where the number of available sensor nodes as well as their power availability is constrained [12]. Therefore, it follows that the allocation of material is a difficult process that must be performed to service effectiveness, reliability, space, and time continuity . The most crucial factors in determining network efficiency, for example, in an application of area surveillance are coverage thoroughness and continuity across time. It is necessary to define proper resource control algorithms and associated communication protocols that ensure modest energy usage to achieve the targeted coverage level in time and space [13]. The abovementioned scenarios illustrate how crucial the size of the system and management of resources is for the implementation of WSNs in smart cities.

In a WSN, routing is a fundamental service that is necessary for sensors to detect data utilizing individual, low-cost sensor nodes and send the information to the sink for inference [14]. There have been numerous strategies and protocols developed for routing as well as aggregation of data in WSN since the invention of the technology in the 1960s. Even though sensors are getting more intelligent, affordable, and compact, they have always been power limited [15]. Hence, there is a critical necessity to create new, energy-efficient routing strategies. In the aforementioned applications, it is common for data to pass through a lengthy chain of intermediary sensors before it is sent to the sink. Therefore, multi-hop routing uses a lot of the WSN's power [16].

Countless protocols of routing were created for the IoT-based WSN. RPL is one of the promising protocols for routing lossy, low-power networks. The IETF certified the RPL IPv6 protocol of routing in 2012, and it is in use with the IoTs [17].

A. Research Objective

- This research aims to implement an ad-hoc protocol of routing for hybrid MCS-WSN in the setting of smart cities.
- To overcome the challenges of WSN and MCS sensing networks through the integration in an opportunistic method.
- To employ ad hoc routing protocol for MCS in a smart city administration.

B. Research Layout

Therefore, the subsequent of this research article is structured as below. The review of the literature is described in section 2, and the research methodology is analyzed in section 3. The outcomes are illustrated in Section 4 and analyzed. The research article's conclusion is depicted in the last section 5.

II. LITERATURE REVIEW

The studies performed on WSNs encompass more than just sensor networks and the algorithms employed to gather and evaluate the data; it also comprises system integration. For example, cloud computing, robotics, satellite, wireless data communication, etc. The necessity to save the necessary elements and components to develop numerous WSN initiatives has a noteworthy influence on many fields and industrial areas .

The researchers of [18] developed Opp-Net, which comprises three different stages: data collecting, data relay, and data posting. Sensors with Opp-Net access communicate their information to the system middleware employing Bluetooth during the data-collecting stage so that it may be transmitted to the mobile system, which is managed by a queue manager. For practical uses, in which sensed data must be delivered straight to the server, it is inapplicable. Additionally, whenever mobile nodes are installed, this solution does not account for the expense of identifying, querying, and maintaining fixed node routing.

Routing has indeed been a major challenge for WSNs ever since its inception in the 1970s. For data collection and routing that is energy efficient, numerous strategies have been suggested. Routing using mobile sinks, cross-network protocols, as well as routing using heterogeneous sensory nodes are a few of these. One might refer to a couple of recent studies by [19] for further information. Utilizing a couple of higher-power longer-range devices in a system of shorter-ranging sensor nodes is an intriguing research topic connected to this research. For example, show how a small number of long-range sensors can significantly improve network lifespan and delivery ratio.

Routing protocols have been reviewed in light of smart cities and IoT applications. Most IoT routing, as well as data aggregation, systems can indeed be divided into two categories. One is specifically relevant to IoT uses, where the study analyses IoT application needs and advises adjusting or making a protocol compatible with the new application area.

For example, IoT systems, [20] provide an enhancement to the AODV ad hoc-based routing protocol that takes into account QoS (Quality of Service), dependability, and energy efficiency. The AODV protocol is additionally improved by] employing a probabilistic strategy to lengthen network lifespan and spend less power. Some publications concentrate on particular WSN types, like wireless multimedia sensor networks. The operational aspect (route) that describes why the movable units communicate and why the signals move among them is not covered by this architecture.

In [21], the researchers suggested adapting the RPL routing protocol for VANET by changing the minimal rank plus hysteresis objective functionality (MRHOF) to take delay into account as a routing factor. The research has been assessed and contrasted with OF0 and MRHOF, the native RPL target factors. The evaluation's findings indicated that RPL may be appropriately adjusted to function in a vehicle context. But, to address the network dynamic shift brought on by vehicle motion, these suggested methods disable the trickling algorithm. Due to the frequent requirement for a significant variety of control signals, this raises network overhead.

Everyone is aware that the internet of undersea things (IoUT) is indeed a highly advanced IoT debate. [22] depicts that, Underwater wireless sensor networks (UWSNs) have emerged as a possible platform to support the concept of IoUT. IoUT is described as a network of dazzling, reliable, underground objects. IoUT is needed to enable a variety of operational uses, such as environmental observation, underwater research, and crisis management. IoUT is thought to be among the hidden innovations for smart city growth. The IoUT is described as a comprehensive system of intelligently linked underwater objects that enable to screen of enormous uncharted sea regions. The objective of the experiment is to evaluate how to employ the IoUT to benefit from exploration and protect common underwater resources. The researchers discuss the differences between UWSNs and conventional TWSNs-territorial wireless sensor networks, and these variations are the main challenges for IoUT with different routing protocols.

This research differs from the above in that our sensors operate in a variety of activity patterns and look for nearby IoT devices, but their core concept is the usage of context-oriented design by smart devices. In addition, the sensors conserve energy by going into a sleep state when they are not in use. To provide the information to the mobile user, [23] incorporate a current smart structure of WSN to the context of IoT via portals and the primary server. But they link WSN using the Internet and subsequently the mobile user; their activity has nothing to do with making use of IoT devices.

III. METHODOLOGY

A. Selection of RPL Protocol

The reasons for choosing RPL as the foundation for the protocol are as follows: RPL is predominantly built for data collecting, supporting mostly multipoint-to-point communication, which is analogous to the traffic stream in the MCS as well as WSN scenarios. RPL could also be operated in front of other MAC layers. As a result, employing built-in Wi-Fi in cellphones (in this case, the MCS) and MAC in static WSNs is advantageous. It is critical for integration to have multiple node kinds that utilize the identical protocol. The routing signals may be simply understood and exchanged between the 2 sites. RPL is a protocol that is built on trees. The capacity to manage sensing and system development is the key essential justification that a tree-oriented topology is a preferable option for sensing applications.

B. Methods and Simulation Configuration

Validating the impact of the combination among the nodes of WSN and MCS in the WSN nodes is the major target of the assessment in this study. This research examines if this hybrid protocol helps the nodes of WSN and addresses certain earlier listed native protocol problems, including hot spot (HS), packet distribution, latency, and node lifespan. The parameters for measuring performance include the average end-to-end (E2E) latency, the PDR-packet delivery ratio, and the average power usage.

PDR=Number of packets received/number of packets sent

The solitary node that obtains data packets yet does not transmit them in multiple point-to-point situations is the sink. Transmitters are only present from the other nodes. When a packet is issued by an origin node and obtained by a sink, this is known as E2E latency.

This research employs 2 key situations for the hyper-RPL function assessment. In one case, three MCS node rates at various MCS densities are taken into account. We may then observe the performance of the protocol as a result of the impact of both mobility rate and density. This research was able to simulate individuals moving in a smart city by employing the randomized pointer mobility framework and setting the MCS movement rates to 2, 4, & 6 m per sec. In the randomized pointer mobility sequence, a node chooses a randomized target site and a randomized rate between 0 and a certain optimum rate. The node then travels randomly for some time, pauses in the middle for a fixed period, and then starts moving randomly over. Additionally, the study set the MCS node count to 150, 100, 75, and 50 to examine how the protocol functions at various densities.

The alternative situation accounts for various WSN data flow with various MCS node densities. This study raises the WSN-based traffic in every test to examine the response of the protocol to the increased traffic volume. This study also fixes each WSN node's speed of traffic generation to one packet per 5, 3, and 1s. The study adjusts the MCS node counts to 150, 100, 75, and 50 for each traffic speed. In all of these testing of this situation, the study fixes the MCS rate to 2 m per sec.

This study fixes the WSN node count at 80 in all circumstances. It recreates the situation in which WSN nodes are often deployed in static locations that hardly ever shift but MCS nodes, which stand in for individuals, move occasionally. The parameters of setup for the implementation situations are shown in Table I.

TABLE I THE PARAMETERS OF THE SIMULATION SETUP OF HYPER-RPL

Parameters	**Readings**
Area	800*800ms
Size of the cell	100m
Simulation period	300sec
WSN node counts	80
MCS node counts	150, 100, 75, and 50
Radio range of WSN counts	60m
Radio range of MCS counts	250m
Traffic generation speed of UDP app	1, 2, and 5sce
Packet generation of UDP app	Starts at 5 sec and ends at 300 sec
Mobility type of MCS nodes	Randomized route pointers
Mobility rate of MCS nodes	2,4,6 mps

IV. RESULT AND DISCUSSION

Figure 1 displays the RPL and hybrid-packet RPL's delivery ratios about the rate and density of MCS nodes.

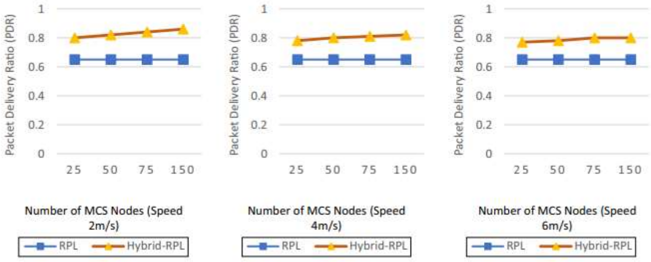

Fig.1. PDR-packet delivery ratio against MCS node count for hybrid-RPL as well as RPL at various MCS node rates

The total average of the hybrid-packet RPL delivery ratio is close to 80% and higher in comparison to the native RPL, which stands just beyond 68% in all MCS node rates and density situations. Additionally, the figure shows the optimum packet distribution that could be accomplished with a modest MCS node of 2 m/s speed and greater densities of 75 nodes and more. This is plainly explained by the notion that incorporating nodes of WSN would last more with lower MCS node speeds than using higher speeds. An MCS node travels to a distinct site more quickly at higher speeds.

The RPL average E2E latency as well as RPL-hybrid for MCS node rate and density is shown in Fig.2.

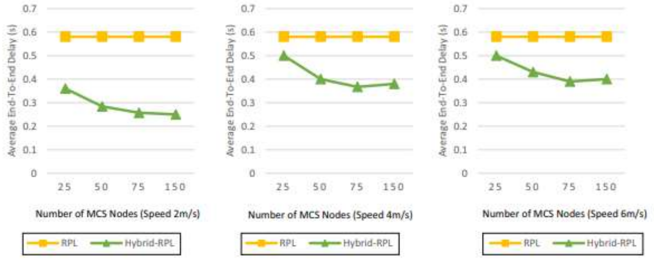

Fig.2. E2E latency against MCS node count for hybrid-RPL as well as RPL at various MCS node rates

Fig.2. demonstrates unequivocally that RPL-hybrid beats RPL in reducing latency across the board. The cases with the optimum latency minimization (higher than 50%) are those having lower rates in the nodes of MCS and significant density. It is related to the prior point that it takes extra effort to merge using WSN nodes when the MCS node rate is insufficient. The likelihood of integrating with WSN nodes is improved by enhancing MCS node density.

The average energy usage of WSN nodes about the MCS node counts for RPL-hybrid as well as RPL at various MCS node rates is shown in Fig.3.

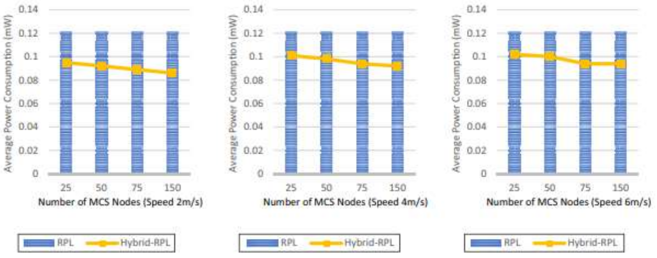

Fig.3. The average energy usage of WSN nodes about the MCS node counts for RPL-hybrid as well as RPL at various MCS node rates

Figure 3 compares the hybrid RPL and the 80-WSN nodes which use the RPL of native in terms of average energy usage. In all simulated situations, it demonstrates the positive effects of WSN-MCS connectivity on the energy usage of WSN nodes. This is due to certain WSN traffic (that complies with the integration standards) choosing to follow the MCS tree route rather than the standard route. From the viewpoint of the WSN nodes, this traffic and indeed the accompanying energy usage are conserved. The MCS lower-rate and high-density situation result in the optimum hybrid-RPL energy usage drop.

The HS nodes' average energy usage is displayed in Fig.4.

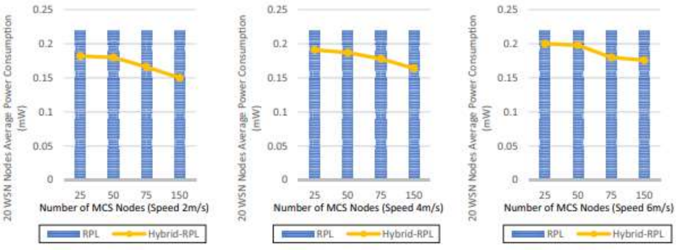

Fig.4. 20 WSN HS nodes' average energy usage about the hybrid RPL MCS node counts as well as RPL at various MCS node rates

In comparing this investigation with the previous studies' energy usage, the largest problem with restricted IoT devices, like WSN nodes, is power consumption. The Radio's broadcast Tx energy and reception Rx energy are the primary sources of energy usage that exhaust these equipment's batteries [24]. On the contrary, sending or accepting additional information or controlling packages means using up the additional battery, which ultimately shortens the node's lifespan. The majority of WSN systems view the increased pressure at HS nodes as a problem. Nearer to the washbasin are these connections. These nodes typically transport more traffic over different nodes.

The HS nodes transmit higher data than normal nodes as per Fig.4. These nodes consume more energy than the rest, at a rate of more than 40%. The stability of the entire WSN network would be impacted by this. Despite being more crucial due to their function in carrying, these nodes would perish more quickly than the others.

Fig.5. displays the RPL-hybrid and RPL PDR about the density of the nodes of MCS and the traffic of WSN.

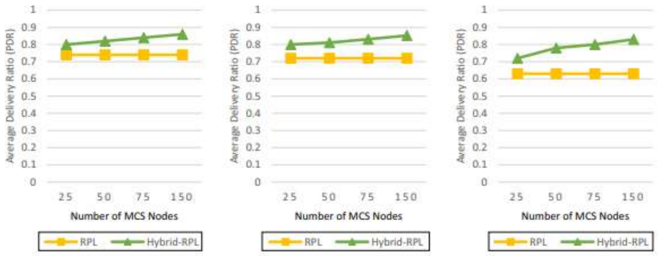

Fig.5. PDR versus MCS node count for hybrid-RPL as well as RPL for various WSN node traffic speeds

It demonstrates that hybrid RPL retains a strong PDR of close to 80 percent and that it is not significantly impacted by rising traffic. In opposition, the native RPL PDR decreases as traffic volume rises. Whenever there is higher traffic, there are additional data packet interceptions. By utilizing MCS nodes, which operate on a separate radio frequency, to route a portion of the traffic (produced by WSN edge nodes), Hybrid-RPL lessens collisions. The graph also demonstrates how increasing the MCS nodes density improves PDR. The possibilities of integration using WSN nodes increase with the number of MCS nodes.

The connection between the end-to-end latency and the traffic rate is depicted in Fig.6.

While using composite-RPL, the lag is decreased since a portion of the traffic is carried by MCS sites on account of WSN sites. Although the rise in WSN traffic, MCS units may nevertheless handle part of this traffic (produced at border units), reducing traffic accidents. Moreover, the traffic sent to MCS nodes would get to the washbasin quicker than it would via the standard WSN route. The lag would also be reduced with additional MCS nodes because there are more opportunities for WSN-MCS fusion.

When compared to native RPL, among the largest notable performance enhancements of hybrid RPL is the reduction of the latency in transferring detected packages to the washbasin. Fig.2, 5, and 6 demonstrate the increase in performance. When integrating with MCS sites, the protocol significantly increases the performance of the fixed WSN endpoints compared with native RPL (non-integrated).

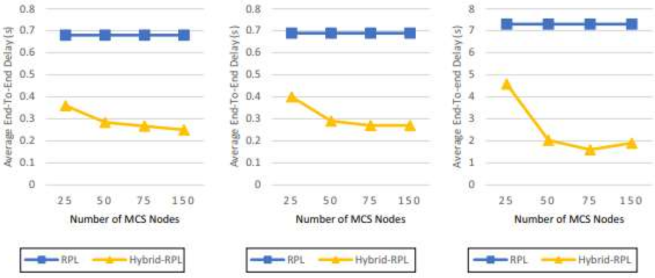

Fig.6. E2E latency versus the MCS node counts for RPL-hybrid as well as RPL at various WSN node traffic speeds

It can be shown that whenever WSN nodes produced traffic at a speed of a single packet per sec, the latency grew significantly (higher traffic). According to the graph, hybrid-RPL outperforms RPL in all evaluated circumstances by reducing the latency by higher than 50%. Whenever the traffic is strong and there are more MCS nodes present (75–150), the reduction is readily visible. The decrease has surpassed 75% in these circumstances. The escalation in packet collision rates under heavy traffic is the reason for the latency extension.

Fig.7. displays the average energy usage of the hybrid RPL and RPL of the nodes of WSN.

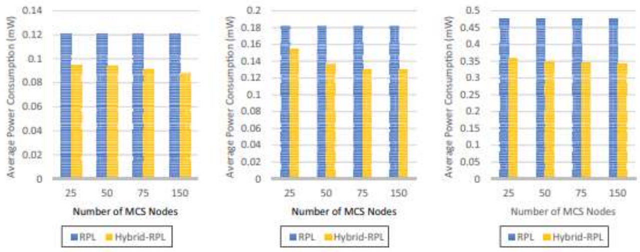

Fig.7. 20 HS WSN nodes' average energy usage compared to the MCS node count for hybrid RPL as well as RPL for various WSN node traffic speeds

In connection to data traffic, Fig.7. displays the average energy usage of the hybrid RPL and RPL of the nodes of WSN. As traffic volume rises, so does electricity usage. This rise is anticipated since higher traffic entails additional Rx receptions, and Tx transmissions both of which rise energy usage. Hybrid-RPL lowers the energy usage in WSN nodes because its function is to support the WSN nodes (through absorbing a few of their traffic and routing it via MCS nodes). Compared to RPL, hybrid-RPL uses about 25% less energy. Whenever the WSN traffic rises and there are additional MCS nodes active, this may be seen since additional MCS nodes are engaged in transmitting this traffic in the tree.

V. CONCLUSION

Modern society is constantly upgrading to and accepting the emerging IoT and Smart City concepts as they present new possibilities to adopt and take advantage in addition to new needs and problems. Additionally, it is necessary to combine current systems using fresh concepts that make use of fresh architectures and systems.

On both MCS and fixed WSN nodes, this study has suggested a hybrid-RPL routing mechanism. Instead of employing 3G or LTE, which potentially be expensive, the protocol gathers and routes detected data ad hoc from MCS units to the centralized device. The combination of the MCS nodes and fixed WSN is made possible by hybrid-RPL in an advantageous manner. For various network levels, mobile node rates, and traffic intensities, the protocols are created, simulated, and tested on OM-Net. After incorporation using the MCS nodes, the protocol significantly outperformed native RPL in terms of functionality for the fixed WSN nodes. For various MCS rates and network densities, the average rise in the packet delivery proportion was 17%, the end-to-end latency has been 50% lower, and the energy usage was 25% lower. Whenever the data traffic of WSN increases, Hybrid-RPL retains outstanding functionality with 20% higher PDR, 75% lower E2E latency, as well as 25% reduced energy usage.

Hence, this research believes that the hybrid RPL protocol of routing can indeed be effective for detecting and data acquisition, particularly in the context of smart cities and urban areas. In the long term, the research work plans to improve this protocol by limiting the range of nodes of MCS that can engage in operational sensing on every cell. To safeguard the fusion procedure between the two systems, an authenticating method is planned to implement between MCS and WSN nodes.

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