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Trust-based and Mobility Aware Energy Efficient RoutingProtocol for Internet of Things

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ABSTRACT: Internet of things grew swiftly and many services, software, sensors-embedded electronic devices and related protocols were developed and still in progress with full swing. Internet of things enabling physically existing things to see, hear, think and perform a notable task by allowing them to talk to each other and share useful information while making decision and caring-on/out their important tasks. Internet of things is greatly promoted by wireless sensor network as it becomes a perpetual layer for it. Wireless sensor network works as a base-stone for most of the Internet of things applications. There are severe general and specific threats and technical challenges to Internet of things–based sensor networks which must overcome to ensure adaptation and diffusion of it. Most of the limitations of wireless sensor networks are due to its resource constraint objects nature. The specified open research challenges in Internet of things–based sensor network are power consumption, network lifespan, network throughput, routing and network security. To overcome aforementioned problems, this work aimed to prolong network lifetime, improve throughput, decrease packet latency/packet loss and further improvise in encountering malicious nodes. To further tune the network lifetime in terms of energy, wireless harvesting energy is suggested in proposed three-layer cluster-based wireless sensor network routing protocol. The proposed mechanism is a three-tier clustering technique with implanted security mechanism to encounter malicious activities of sensor nodes and to slant them into blacklist. It is a centred-based clustering protocol, where selection of cluster head and grid head is carried out by sink node based on the value of its cost function. Moreover, hardware-based link quality estimators are used to check link effectiveness and to further improve routing efficiency. At the end, excessive experiments have been carried out to check efficacy of the proposed protocol. It outperforms most of its counterpart protocols such as fuzzy logic–based unequal clustering and ant colony optimization– based routing hybrid, Artificial Bee Colony-SD, enhanced three-layer hybrid clustering mechanism and energy aware multi-hop routing in terms of network lifetime, network throughput, average energy consumption and packet latency.

Keywords— Clustering, energy efficiency, Internet of things, wireless harvesting energy, link quality, network lifespan, three tier, wireless sensor network.

1. INTRODUCTION

Many IoT applications provide ubiquitous services and in- volve Machine-to-Machine (M2M) communication to provide Automation, remote access, and intelligent decision-making without human intervention. For such applications, the numberof P2P traffic flow is significant, and mobility is a fundamentalrequirement [3], [4]. In the dynamic environment where nodesare mobile, maintaining reliable links to prevent packet loss is a challenge. Due to limited energy of nodes, routing protocols have to be energy-efficient. ER-RPL is an energy-efficient routing protocol that provides reliable and nearly optimum P2Proutes [12]. However, it cannot be used for the application thatrequires mobility support. ER-RPL derives its Destination Ori-ented Directed Acyclic Graph (DODAG) creation from RPLto maintain the topology that is optimized for Multipoint-to- Point (M2P) communication. For P2P route discovery, based on region codes of the source and the destination node, only a few required regions are selected. Only nodes which belong toselected regions participate in temporary DODAG creation that results in reducing energy consumption. Our proposed protocolMAEER is an extension of ER-RPL. MAEER inherits key ideaof energy-efficiency from ER-RPL and provides additional mechanisms to support mobility.

WSN is a foundational technology for IoT. Whole IoT system relies on it.[12] WSN plays a strategic role in promotion and growth of IoT, permitting low end devices with limited resources and offering life-changing services. It uses tens to thousands of sensors connecting each other via wireless technology.[13,14] Advancement in sensors' technology makes it possible to build low cost and tiny-sized IoT-enabled wireless sensors to bring smartness in small- to large-scale appliances.[15] A typical WSN composed of numerous numbers of sensors nodes with sensing, communication and processing capabilities.[16,17] WSN can serve as a platform for many other domains such as measurement of important environmental parameters (humidity, temperature, light, pressure and so on) in smart agriculture, secure and reliable communication, military applications and monitoring, medicine and healthcare, different types of industries, traffic surveillance and so on.[17–26]

There are severe threats and technical challenges to WSNs that must be overcome to ensure adaptation and diffusion of it. Most of the limitations of WSNs are due to its resource constraint objects nature. The sensors of open area WSN is always vulnerable to harsh or hostile environment challenges in terms of high temperature, humidity, pressure, dust, rain, snow and so on, which are affecting the operation of WSN, making it essential to have robust and resilience sensor nodes. Furthermore, other general problems and future challenges to WSNs are comprises limited constrained resources, limited communication capability, stability, fault tolerance, bandwidth, mobility, result precision, availability, trust, accountability, heterogeneity, integration, uncontrollable environment, technology and denial of service attack (DoS). Along with aforementioned general challenges, WSNs has specific issues that got much of the researchers' attention. These specified open research challenges of WSN are power consumption, network lifespan, network throughput, wireless routing protocols and network security.

Energy consumption is highly prominent topic in WSN communication. The energy efficiency is a key factor, plays a vital role for the longevity of WSN and influences the whole performance of network.[27] The lifetime of the WSNs depends upon energy level (EL) and considered as one of the main factors in performance evaluation of WSN routing protocol.[11,28] In WSN routing, the energy consumption, residual energy and total energy are always important metrics and parameters while computing cost function (CF).[29,30]
Routing has been always an important factor in any type of communication network. It is always been a challenging job for researchers to route packets to destination efficiently, safely and with minimum overhead. Due to sensors' resource constraint, such as limited energy, limited processing and short communication range, the routing algorithm implementation is a cliffhanger task for the researchers. Countless efforts have been made and still extraordinary efforts are needed in this subject to come up with best solutions.We are summarizing themajor contributions of our proposed protocol as follows:

- *To minimize the effect of mobility on the stability of the network topology*: To achieve this, we are adding mobility flag to DODAG Information Object (DIO) message and Message Request Object (MRO) message. These flags make nodes aware about their neighbors' mobility status.
- *To maintain connectivity of mobile devices to the net- work*: The proposed Dynamic DIS and DIO propagation management maintain the connectivity of nodes.
- *To discover P2P route within application constraints*:MAEER choose static nodes as the parent for temporary DODAG formation.
- *To minimize the energy consumption of nodes*: In our proposed protocol, only some regions participate in P2P route discovery. Selection of participating regions is based on region code information of the source and the destination node.

The rest of the paper is organized as follows. Section II discusses the existing routing protocols and their suitability for P2P traffic and mobility support. The proposed protocol, MAEER is discussed in Section III. Section IV analyzed the obtained results for proposed routing protocol in comparisonto other benchmark routing protocols in the literature. Finally, Section V concludes the paper.

2. BACKGROUND

In recent years IoT has covered wide range of applications [2], [1]. Now, WSN is not just used for monitoring or data collection. It is extended to many IoT applications like automationwhich involves M2M communication for intelligent decision making along with the monitoring [8], [6], [5]. For such appli-cations number of P2P traffic is significant. IoT applications also aim to provide ubiquitous services. Irrespective of time and place, the user should be able to get the service. In such applications, mobility is inherited. Many routing protocolsfor IoT are proposed in the literature. Following subsections discuss the existing routing protocols and their suitability for P2P communication, mobility, and energy-efficiency.

Inspired by above-mentioned consideration, this work aimed to prolong network lifespan, improve throughput, increase number of alive nodes, decrease packet latency and packet loss and reduce energy consumption and further improvise encountering malicious nodes. To further tune the network lifetime in terms of energy, wireless harvesting energy (WHE) is suggested in proposed three-layer cluster-based and IoT-based WSN routing protocol. The proposed solution, trustbased energy-efficient routing protocol (TBEERP), is a three-tier clustering routing protocol with embedded check-up node (CN) to encounter malicious activities of nodes and to slant them into blacklist. Moreover, link quality (LQ) is also checked in order to further improve routing efficiency. Only hardware-based link quality estimators (LQEs) are considered in this proposed research work, which does not overhead or delay the overall process.

RPL constructs a topology of nodes called as Destination Oriented Directed Acyclic Graph (DODAG) which is optimized for M2P communication [11]. RPL uses four control messages to create and maintain DODAG. DODAG Informa-

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tion Solicitation (DIS) message probes neighbor to send DIO. When a node gets enabled, it sends DIS to connect to the net- work. DODAG Information Object (DIO) message helps node to join DODAG, as it contains configuration parameters, RPL Instance, and rank of the sender. Destination Advertisement Object (DAO) propagates destination information upward in DODAG. Destination Advertisement Acknowledgment (DAO- ACK) is sent as an acknowledgment by the recipient of DAO to its sender. RPL maintains the routes by disseminating its control messages using Trickle algorithm [10]. For P2P data flow, RPL gives longer routes as data must follow the existingroutes. Such long routes introduce the delay and bottleneck at the root node. Hence, RPL is not a suitable routing protocolfor applications where P2P data flow is more.

A. Reactive Discovery of Point-to-Point Routes in Low Powerand Lossy Networks (P2P-RPL)

P2P-RPL is an extension of RPL proposed especially for creating optimum P2P routes [9]. It maintains the DODAG optimized for M2P traffic flow. However, for P2P route discov-ery, Source node acts as a temporary root. This temporary root(source) creates a temporary DODAG using functionalitiessame as RPL. P2P-Route Discovery Option (P2P-RDO) in DIO is used to send P2P route request from a source nodeto destination node. After reception of P2P-RDO, destination node replies with P2P-Discovery Reply Object (P2P-DRO) through the same route followed by P2P-RDO. This discov- ered route is used for transmission of data from source to destination. Hence, a route within constraints from source to destination is obtained. P2P-RPL creates temporary DODAG which involves all the nodes in the network. Creation and maintenance of these DODAGs consume energy. Hence, P2P-RPL is costly is terms of energy consumption for LLNs. P2P- RPL behaves same as RPL for mobile nodes. Hence, mobility causes packet loss in P2P-RPL.

B. Mobility Enhanced RPL for Wireless Sensor Networks (ME-RPL)

ME-RPL added mechanisms to native RPL to make RPL more suitable for mobile nodes. This protocol is proposed for static sink scenario [7]. It deals with issues of RPL for mobility. ME-RPL gives priority to the static node rather than mobile node for parent selection to create stable links. Whena mobile node in ME-RPL observes movement, it reducesits DIS interval to half. It results in increasing frequency of DIS sent. In response, the node quickly gets DIOs from neighboring nodes to get connected to the new neighborhood. This results in reduced packet loss as compared to RPL. A node detects mobility by observing the number of parent change in single DIS interval. If the number of parent change exceeds some threshold, then node assumes that it is mobile.In the same way, when a node chooses the same parent more than a threshold it assumes that it is stable.

C. An Energy-efficient Region-based RPL Routing Protocol for Low-Power and Lossy Networks (ER-RPL)

ER-RPL is proposed for a network with static nodes. It divides the whole network into regions and uses this re- gion information to discover P2P routes energy-efficiently. It uses control messages of RPL and trickle timer to maintain DODAG. It also uses its own control messages Region For- mation Object (RFO) and Message Request Object (MRO) for region formation and P2P route discovery respectively.It considers two types of nodes: Reference Nodes (RN) and Normal Nodes. RNs know their locations and are requiredonly to partition the network into regions by sending RFO messages. With this information, nodes calculate logical dis- tances from Reference Nodes (RN) and decide their region by using Distributive self regioning algorithm [12]. Each regionis identified by some identifier called as Region Code (RC). The matrix of Region Codes is called as Region Code Matrix (RCM). For P2P route request, ER-RPL first checks the costof existing RPL route. If the cost is not within the application constraints, it starts its P2P route discovery. In P2P routediscovery, based on the region of source and destination, only few regions (i.e. IRCM matrix which is subset of RCM) are selected to participate in route discovery. In this way, only nodes belonging to IRCM form a temporary DODAG, and source node gets connected to DODAG. Source finds the routeto the destination and sends data through this discovered route.These routes are nearly optimal and satisfy the constraints.We have listed the issues in ER-RPL, which needed to be considered to extend it to support mobility:

1) ER-RPL maintains the topology by creating RPL DODAG. Hence the issues of RPL for mobility are inherited in ER-RPL.

- The mobility of a parent node leaves its childrenunstable. Child nodes detach from the network. To connect to the network again, nodes reset their DIO timer, and frequent transmission of DIOs starts. A Temporary detachment of nodes may cause packets loss, and frequent transmission of DIOs consumes energy.
- When a mobile node comes into the new neigh- borhood, it starts disseminating DIOs due to in- consistency it observes. It needs to connect to the DODAG. This connection is possible only when its neighbors will transmit their DIOs. But these nodes will transmit DIO only when their DIO timer expires.Mobile node has to wait to connect to the network until it receives DIOs. Hence, packet loss is more in RPL when nodes are mobile.

2) In ER-RPL, nodes initially calculates their region codes. If a node changes its region due to mobility, it cannot get its new region. Due to this stale region information, the P2P route discovery fails.

3. PROPOSED PROTOCOL: MAEER

Based on objectives described in Section I, we are extendingthe ER-RPL, by adding some effective approaches to make

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a new routing protocol that supports mobility and discovers nearly optimum P2P routes with reduced energy consumption. Our protocol works as illustrated in Fig.1.

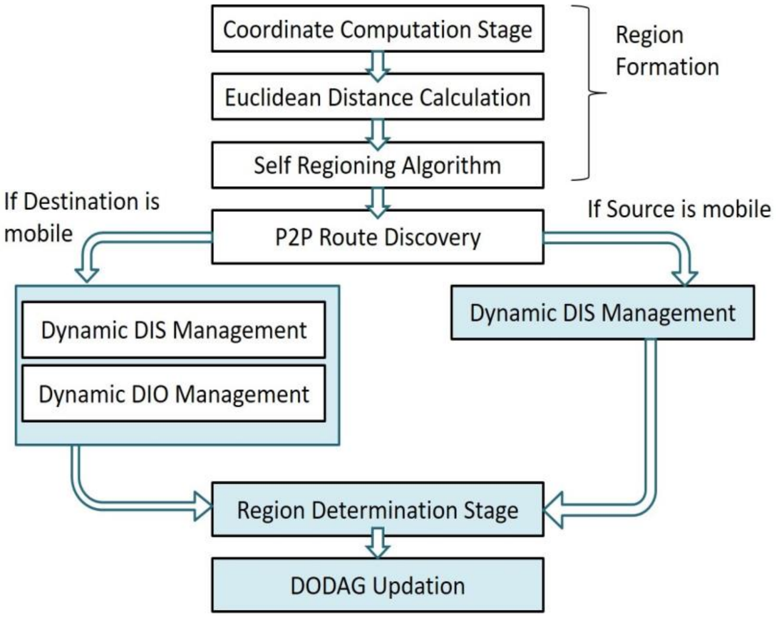

Fig. 1: Flow diagram of proposed protocol

In our proposed protocol, coordinate computation, euclideandistance calculation, and self regioning algorithm work similarto that of ER-RPL. Initially, the RNs send RFOs in coordi- nation computation stage and Euclidean distance calculationto divide nodes in the network into different regions. Each node calculates its region by using Distributive self regioning algorithm [12]. To support mobility in MAEER, the additional proposed mechanisms, dynamic DIS management, dynamic DIS and DIO management, region determination stage and DODAG updation are discussed in further subsections.

A. System Model

We considered n number of nodes densely deployed in the region of size m^2. The number of mobile nodes is considered very less than the number of static nodes. Let T_R be the transmission range of the nodes where T_R m. There are$N$ number of nodes with their location information which are called as reference nodes where N n. We consider that nodes are nearly uniformly deployed with density ρ. In the network, nodes except RNs do not have location information. Initially, to partition the nodes into different regions, self regioning algorithm same as ER-RPL [12] is used.

B. Dynamic DIS Management for mobile source node

MAEER uses RPL to maintain the topology. A mobile nodeshould remain connected to the network to communicate with other nodes. In RPL, when a mobile node moves to a new position, it detects inconsistency due to change in its parent node. Hence, mobile node resets its DIO timer. It results inthe transmission of DIOs from the mobile node. But, it needs information of its new neighbors to connect to the DODAG. Anode solicits this information by sending DIS messages. The rate of transmitting DIS should be dynamic. It should adjust the rate with which topology is changing. When a mobile nodemoves, it changes its parent continuously. Hence, mobilitycan be detected when the number of parent change exceeds a particular threshold. The period between two consecutive DIS transmission is called DIS period. While a node is moving, it increases its rate of transmission of DIS messages by reducingDIS period by half to remain connected to the network. When the node is not moving, or it is in the stable environment,it does not change its parent. Hence, if node chooses thesame parent repeatedly more than a threshold the node will decrease its DIS transmission by doubling the DIS period. To dynamically adjust the rate of transmission of DIS messagesin case of mobility, Dynamic DIS management similar to ME-RPL is used [7].

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Algorithm 1 Dynamic DIS and DIO Management for mobile destination node

```
begin
if new_child_added = 1 then
    child_added = child_added + 1
end if
if child_added ≥ Min child added then
    if DIS_period ≥ 2 * Min_DIS_I then
        DIS_period = DIS_period / 2
    end if
    if DIO_period ≥ 2 * Min_DIO_I then
```

Algorithm 2 Region Determination Stage and DODAG updation

```
begin
if N_s ≥ threshold then
    No change in region
else
    if Max(Ω) is unique then
        New_Region = region of Max(Ω)
    else
        New_Region = region nearest to destination Max(Ω)
        Where region nearest to destination means the region code with
        least size of IRCM
    end if
end if
if New_Region ∈ IRCM then
    Do nothing
else
    Source triggers MRO(3) with updated source region code value
end if
New IRCM is calculated at each node
Nodes from new IRCM joins the DODAG
Nodes that does not belong to new IRCM leaves the DODAG
```

C. Extension of DIO

Mobility should least effect the stability of the network. Maintaining connectivity to the network also should not cost high energy depletion. Mobile nodes create links that are unstable. To maintain the topology and fresh links, frequent control message dissemination is required which consumesthe energy of nodes. To reduce this energy consumption, a node should link with static node rather than a mobile node.It reduces the chance of instability of links due to mobilityof nodes. We are extending DIO control message to add 'Mobility flag', and 'Region Code' fields. Due to this added information, all nodes are aware of their neighbors' mobility status and region code information. Whiletopology formation, a node should not choose mobile nodeas its preferred parent because the movement of parent node makes the network more inconsistent than that of the leaf node. Mobility flag from neighbors enables a node to choose static node as a parent over the mobile nodes. Region code information in DIO allows the protocol to take advantage of region information of nodes. With the help of this field, IRCMcan dynamically change with the new position of mobile source or destination. Dynamic IRCM ensures the reduced energy consumption.

D. Dynamic DIS and DIO Management for mobile destinationnode

In ER-RPL, destination node acts as a root node for P2P path discovery. Root node does not have a parent but has children. Wherever root moves, new nodes get attached toit. Based on the number of new children added in particular DIS period we can detect mobility. The rate of DIS trans- mission and DIO transmission will increase if the number of new children added is more than threshold Min child added. Destination node requires DIOs of other nodes to get region information about its surrounding. It will transmit DIOs with the high rate so that network should always be connected to it. In this paper, algorithm 1 is proposed for the mobile destination node to maintain connectivity. In algorithm 1, DIS period can attain minimum value as Min DIS I and maxi- mum value as Max DIS I. DIO period refers to the interval between transmission of two consecutive DIOs. Min DIO I and Max DIO I denotes the minimum and maximum period between two DIOs transmission respectively. The boolean variable new child added is set to 1 if a new child is added

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to the mobile node.

Type	Start Point Address	End Point Address	Sequence Number	Lifetime
Source Region Code	Destination Region Code	Accumulated ETX	Hop	Mobility flag

Fig. 3: Modified Message Request Object

E. *Temporary DODAG creation*

By forming temporary DODAG with root node, the root node can find optimum routes to every other participatingnode and vice versa. This concept is used by P2P-RPL and ER-RPL to find optimum P2P routes. For temporary DODAG creation, nodes in P2P-RPL and ER-RPL use the metric Expected Transmission Count (ETX) to select theirparent. But, if the intermediary node of discovered P2P route moves out of transmission range of its children, the routewill become invalid. We are extending RFO message to add a field as mobility flag as shown in Fig. 3 due to which nodes know mobility status about their neighbors during P2P route discovery. In our protocol, a node will choose a static node with minimum ETX as its parent. This will reduce the chance of inconsistency due to movement of intermediary nodes.

F. *Region Determination Stage and DODAG updation*

ER-RPL route data with efficient energy consumption by taking advantage of region information of nodes. ER-RPL is proposed for static nodes hence region discovery is done only once when the network is initialized. When a mobile node moves out of its region, its RC information becomes invalid. With this invalid information, the whole P2P route discovery process fails. In ER-RPL, for a particular P2P route discovery, IRCM calculation is done only once. Because of mobility in the network, nodes change their regions and for energy efficient routing they should be aware of their new region code. DIS message dissemination from mobile node results in the transmission of the DIOs from neighboring nodes which includes region code of the neighbor nodes. This regioncode information of neighbors helps the mobile node to get itsnew region code. With the the change in the region of mobile node, the regions participating in DODAG formation should change dynamically. While a node is moving, nodes around it should join the DODAG. This will ensure the connectivity. Moreover, the nodes which were part of DODAG and arenow away from source, as well as destination nodes, should leave the temporary DODAG. Algorithm 2 is proposed for region determination and DODAG updation. Following arethe notations used in algorithm 2. The network is uniformly dense with density ρ and nodes have transmission range T_R. Let r be the maximum number of regions from which a node receives DIOs at particular instance.

Parameters	**Value**
Number of nodes in network	100
Area of network	$180 \times 180\ m^2$
Transmission range (T_R)	$35\ m$
Packet size	512 *bytes*
Routing Metric	ETX
Simulation runtime	1000 *sec*
Transmitter electronics	$50 nJ/bit$
Transmit amplifier	$100 pJ/bit/m^2$
Platform used	Tmote Sky

TABLE I: Simulation environment

4. SIMULATION RESULT AND ANALYSIS

We have considered a scenario where 100 nodes are deployed in 180m 180m area. There are four RNs in the network. For each traffic flow of 90 seconds, the source node and the destination node are randomly selected. We analyzed performance metrics for 10 to 40 number of P2P traffic flow. The simulation parameter used for comparing the protocols is given in Table I.

A. *Performance Metrics*

We have compared the performance of our proposed MAEER protocol with RPL, P2P-RPL and ME-RPL protocolson the basis of following metrics:

(i) *Packet delivery ratio (PDR):* Due to movement of the node in the network, links associated to it become invalid.

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These invalid links are unreliable and result in packet drop in the network. Hence, to assess the reliability of links in our network we used packet deliveryratio as one of the parameters. In a network, new links form when fresh control messages are exchanged among the nodes. Our proposed protocol increases the frequency of control message dissemination during movement of nodes to refresh the links.

(ii) *Energy consumption per data packet successfully deliv- ered:* This metric evaluates the energy efficiency of our protocol. It is calculated as total energy consumed in a network per data packet successfully delivered.

(iii) *Average hop count:* Hop count is an approximate mea- sure of route distance. At each hop, messages are pro- cessed and forwarded. This results in added delay. More hop count introduces more delay.

B. Performance Analysis

In Fig. 4a, we observed that the energy consumption of MAEER is less than P2P-RPL by 22%, 24% and 10% at number of P2P traffic flow 10, 25, and 40 respectively which isbest among RPL, P2P-RPL, and ME-RPL. P2P-RPL includes every node in the network for P2P route discovery. It consumesalmost same energy throughout the simulation. It is because the energy of every node is consumed irrespective of thedistance of source to the destination node and number ofP2P traffic. While for proposed protocol, only selected regionsparticipate in P2P route discovery which saves energy of nodeswhich are not selected. This gives a significant reduction in energy consumption of nodes. But energy consumption increases with more number of P2P traffic since participating nodes increases. In RPL and ME-RPL for P2P traffic, root get congested and packets are lost which results in retransmission of data packets.

In Fig. 4b, we can observe that PDR of our proposed protocol is better than ME-RPL by 5%, 15%, and 13.6% at number of P2P traffic flow 10, 25, and 40 respectively which is best among RPL, P2P-RPL, and ME-RPL. In our protocol, node quickly refreshes the routes when node detects inconsistency which results in more valid routes than P2P- RPL. This eventually increases PDR. In RPL, and ME-RPL P2P traffic has to go through the root which causes the congestion and packet loss.

In Fig. 4c, hop count for MAEER protocol and P2P-RPL arenearly equal and better than RPL and ME-RPL. It is because our protocol creates the temporary DODAG in selected regionsimilar to that of P2P-RPL. But in RPL, and ME-RPL hop count is more because of routing over existing routes.

In Fig. 4d, energy consumption is analyzed for RPL, P2P- RPL, ME-RPL, and MAEER with respect to Max_DIO_I. Increase in Max_DIO_I decrease the frequency of transmission and hence energy consumption decreases. We can also observethat energy consumption of our proposed protocol is much lower than others for all values of Max_ DIO_ I.

Fig. 5a shows that energy consumption is higher for lower value of Min_DIO_I. With increase in Min_DIO_I, transmission of control messages is delayed and their frequency of dissemination decreases. This results in lower energy consumption. For lower value of Min child added, mobility detection is quicker. This causes early and frequent transmission of control messages which consumes more energy.

In Fig. 5b, we can observe that with the increase in Min_DIO_I, the frequency of transmission of DIO messages decreases. Change in routes is not refreshed due to delayed DIO messages which result in packet loss. But the too low value of Min_DIO_I causes congestion. The performance is evaluated for 3 values of Min child added. With setting this threshold value low mobility is detected quickly and packet loss can be prevented.

Fig. 5c shows the energy consumption for different values of Min_ Parent_ Change with respect to change in the valueof Min_DIS_I. We can observe that energy consumption for lower values of Min_ Parent_ Change and Min_ DIS_ I is higher.

In Fig. 5d, PDR for Min_DIS_I is calculated for different Min_Parent_Changed values. From this graph, we observe that PDR is better when Min_Parent_Change is 1. Low threshold value enables early detection of mobility and triggers dissemination of control messages.

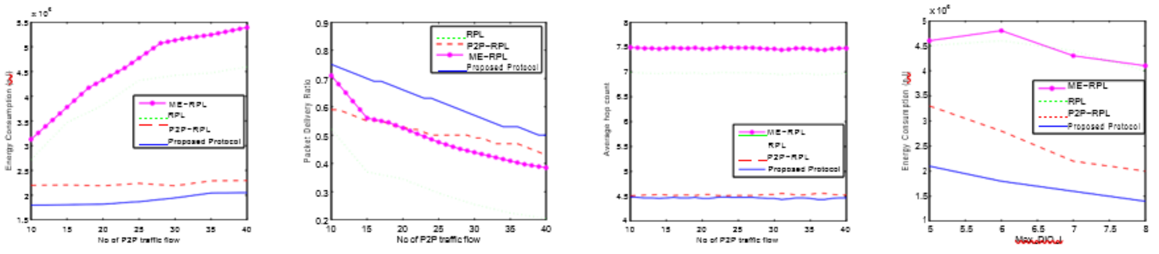

Fig. 4: Performance Measure: (a) Energy consumption with respect to Number of P2P traffic (b) Packet delivery ratio with respect to Number of P2P traffic (c) Hop count with respect to Number of P2P traffic (d) Energy Consumption with respect to Max_DIO_I for RPL, P2P-RPL, ME-RPL and MAEER

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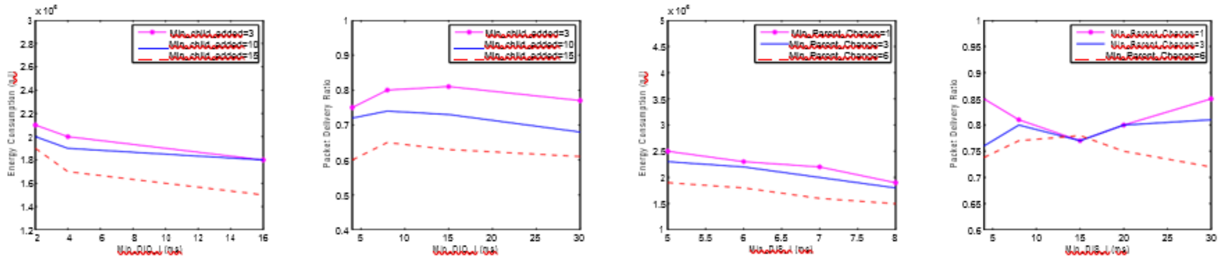

(a) (b) (c) (d)

Fig. 5: Performance Measure: (a) Energy consumption with respect to Min DIO I for different values of Min child_added (b) Packet delivery ratio with respect to Min_DIO_I for different values of Min_child_added (c) Energy consumption with respect to Min_DIS _I for different values of Min _Parent_ Change (d) Packet delivery ratio with respect to Min _DIS _I for different values of Min_Parent_Change

CONCLUSION

We have analyzed our MAEER protocol on different parameters and compared with RPL, P2P-RPL, ME-RPL, and ER-RPL. Based on the observations of results, we can conclude that energy consumption of MAEER is 24% lessthan P2P-RPL which is best among RPL, P2P-RPL, and ME-RPL. PDR of MAEER is 15% better than ME-RPL which provides best PDR among the three. Energy con- sumption decreases with increase in Min_DIO_I, Min_DIS_I, and Max_DIO_I. PDR decreases with increases in values of Min_DIS_I, Min_DIO_I. This shows that there is a trade-off between energy consumption and PDR. Based on our analysis values for Min_DIS_ I, Min_ DIO_ I, Max_ DIO_ I, Min_ Parent_ Changed, Min_ child_ added should be 8*ms*, 8*ms*, 8, 3 and 3 respectively. With the increase in P2P traffic, energy consumption increases and PDR decreases. We analysed ER-RPL and MAEER and observed that both have higher memory requirement than that of RPL and ER-RPL.

REFERENCES

[1] 50 sensor applications for a smarter world. http://www.libelium.com/ resources/top 50 iot sensor applications ranking. [Accessed: 2016-20-5].

[2] Application areas for the internet of things. http://www.ti.com/ww/en/ internet of things/iot-applications.html. [Accessed: 2016-20-5].

[3] Internet of things p2p software connection platform. https://universe.ida.dk/meetupfiles/download/?meetupNumber= 310457&filename=Nabto-short-aau.pdf. [Accessed: 2017-05-11].

[4] Iot messaging should we head for the cloud or p2p? https://bloggeek.me/messaging-iot-p2p/, October 2015. [Accessed: 2017-05-11].

[5] G. Porcu A. Brandt, J. Buron. Home automation routing requirementsin low-power and lossy networks. 2010.

[6] P. Thubert Ed. S. Dwars T. Phinney K. Pister, Ed. Industrial routingrequirements in low-power and lossy networks. 2009.

[7] I. E. Korbi, M. Ben Brahim, C. Adjih, and L. A. Saidane. Mobility enhanced rpl for wireless sensor networks. In *2012 Third International Conference on The Network of the Future (NOF)*, pages 1–8, Nov 2012.

[8] T. Watteyne Ed. T. Winter Ed. D. Barthe M. Dohler, Ed. Routing requirements for urban low-power and lossy networks. 2009.

[9] E. Baccelli M. Philipp A. Brandt J. Martocci M. Goyal, Ed. Reactive discovery of point-to-point routes in low power and lossy networks. 2013.

[10] O. Gnawali J. Hui J. Ko P. Levis, T. Clausen. The trickle algorithm. March 2011.

[11] P. Thubert Ed. A. Brandt J. Hui R. Kelsey P. Levis K. Pister R. Struik JP. Vasseur R. Alexander T. Winter, Ed. Rpl: Ipv6 routing protocol for low-power and lossy networks. 2012.

[12] M. Zhao, I. W. H. Ho, and P. H. J. Chong. An energy-efficient region- based rpl routing protocol for low-power and lossy networks. *IEEE Internet of Things Journal*, 3(6):1319–1333, Dec 2016.