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MULTICAST GROUP MANAGEMENT BASED RPL FOR POINT TO MULTIPOINT MULTIMODAL DATA COMMUNICATION

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Abstract

In an Internet of Things(IoT) network, a base station fetches data associated with various sensors in the network via multicast queries. When a query reaches a node, the node responds back to the query if it supports that sensor in addition to forwarding the query further down the network. This way the queries can land on parts of the network that don't support any of the sensors leading to wastage of bandwidth and energy. To overcome this drawback, a multicast group management scheme is proposed that optimizes the forwarding of the multicast address based queries in an IoT network. The proposed work is implemented in ContikiOS and executed as a simulation on Cooja as well as on a real time IoT network, FiTIoT-Lab. The results of the simulation indicate that the proposed method outperforms with the existing method in the overall network. Experimental results mention that the proposed method improves PDR for 2 level and 3 level topology by 35.03% and 28.18% respectively.

Keywords: IoT, Multicast, Query, Routing, 6LoWPAN

1. Introduction

An Internet of Things(IoT) network comprises of heterogeneous set of IoT nodes. Each of these nodes houses one or more sensors. With the advancement in semiconductor technology, a variety of low-end devices are becoming part of

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the Internet. The scale of such devices is huge and to help [1] connect them to the Internet is challenge. In order to leverage the Internet protocol (IP) which is the backbone of the Internet to connect such devices, IETF developed the IPv6 low-power wireless personal area networks (6LoWPAN) which is used as an adaptation layer on top of the IP stack. This adaptation layer enables the use of new routing protocols that can connect the low-end devices to the Internet. The design paradigms of conventional routing protocols does not fit well in the world of Internet of Things (IoT).

RPL is an IPv6 based routing protocol designed specifically for Low-Power and Lossy Networks. RPL is designed with the goal to connect millions of resource-scarce devices. It uses a Destination Oriented Directed Acyclic Graph (DODAG) topology and enable nodes in the network to communicate while storing minimal routing state information. RPL provides permission to allow traffic on both upward and downward routes. Upward routes are constructed from the earliest process of DIO (DODAG Information Object) messages. But Downward route directs the use of DAO(Destination Advertisement Object) messages. two modes of operations are used. One is the Non-storing mode and another one is storing mode used for the Multicast application.

The low-end devices [2] are embedded with multiple sensors and gather a variety of data through these sensors. The devices don't have a lot of memory or compute to store and process these information. Additionally, they don't have a big energy store to keep the sensors turned on all the time. A remote node controls the state of the sensors on each node. It also periodically collects the sensor data from all the nodes for storage and processing.

The remote node uses multicast frames to control or query multiple nodes at the same time. Multicast allows a single source to communicate with a set of destinations using reduced number of network resources. The frames are destined to a multicast address based on the sensor being controlled or queried. The multicast address used for a sensor may not be static. Also, multiple sensors can be controlled or queried with the same multicast address.

1. The node responds back to the query if the query is for a sensor it supports.
2. The node forwards the query further down the network.

While this workflow does work, it suffers from 2 major drawbacks.

1. Each node must be statically configured with all the multicast addresses that can be used for queries. This increases the size of the multicast address table required on the node and the size of the multicast routing table on the upstream nodes.
2. The queries can land on parts of the network that don't support any of the sensors that it is intended for wasting the network bandwidth and in turn energy.

Address compression and sensor grouping scheme is proposed to optimise the routing table and query dissemination.

The structure of the report is organized as follows. In section 2, brief literature review on different multicast protocols and research gaps have been discussed. In section 3, detailed description of multicast address groups for sensor has been mentioned and also it includes multicast sensor group advertisement, multicast sensor group and leave, route refresh, address compression and sub-option payload with different grouping and compression scheme has been discussed. In section 4, covers the details of experimental setup conducted in cooja and using Fit-IoT lab setup. Followed by summary, conclusion and future work in section 5 and 6 respectively.

2. Related Work

In paper [3] discusses the various challenges of adopting multicast in IPv6 networks with resource constrained devices. Trickle Multicast (TM), the multicast protocol for low power and lossy networks, is a step in the right direction to address some of the challenges in adopting multicast in such networks. TM uses flooding governed by the trickle algorithm. Trickle is a technique wherein the frequency of periodic information exchange between neighbor nodes decreases

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exponentially when they share the same status. This saves energy and improves the bandwidth efficiency. When a change is discovered, the trickle timer is reset to a minimum interval to ensure the change is propagated to all the neighbors within milliseconds and they can converge to the same status. Each node in the network broadcasts the multicast packets to all of its neighbors. A sequence number is associated with every packet as an extension option inside the IPv6 header to ensure there are no duplicate multicast packets in the network. It's merits include it can fit alongside any routing protocol without any modifications, it guarantees a higher packet delivery ratio with no duplicates, While TM has its merits, it also has certain shortcomings which include lack of scalability due to maintenance of per packet state information, low in performance due to delays in forwarding a frame to ensure there are no duplicates, lack of topology maintenance that results in the packets to be flooded in the entire network irrespective of if it's needed or not, susceptibility to out of order packets.

The paper [4] introduces stateless multicast RPL forwarding algorithm (SMRF), that is designed to overcome the shortcoming of the current multicast solutions for low power lossy networks. Nodes in a RPL network exchange topology information to build a Destination Oriented Directed Acyclic Graph (DODAG) and SMRF leverages this property of RPL for efficient multicast forwarding. When the storing mode of operation is used in RPL, nodes join a multicast group advertising it's address in the outgoing DAO messages upward in the tree. The nodes that receive this message make an entry for this multicast address in their routing table. The node then advertises this address in it's own DAO messages and also forwards any frames destined to this multicast address downward in the tree.

This suffers from two drawbacks - there is no way to stop a node from accepting the same datagram more than once, the node needs to transmit the same multicast frame multiple times, once for every node that is participating in this multicast address group. SMRF overcomes both these drawbacks by - accepting multicast frames on a node only if received from it's preferred parent, forward the multicast frame further only if there is an entry for that specific

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address in it's multicast routing table.

The performance of TM and SMRF is compared for several metrics including packet delivery ratio, end-to-end delay, out-of-order datagram delivery ratio and energy consumption. Four different topologies, one line and three tree topologies are used for comparisons. The results show SMRF in exchange for an occasional slight reliability drop is both faster and more energy efficient.

The paper [5] introduces Enhanced Stateless Multicast RPL Forwarding (ESMRF), which is an improvement over the existing SMRF scheme. SMRF suffers from a drawback. The multicast traffic can only flow downwards in the RPL tree. In other words, while the source of the multicast stream can be anywhere in the network, it can only stream that data downwards in the RPL tree. Nodes that are sitting above the multicast source node also registered to the same multicast address drop the stream since it isn't received from their preferred parent. ESMRF eliminates this limitation and allows the multicast traffic to traverse both upward and downward a RPL tree. While ESMRF reuses the same acceptance and forwarding model of SMRF, it adds multicast-on-behalf features at the RPL DODAG root.

For a node to send a multicast data frame, the packet is encapsulated inside an Internet Control Message Protocol version 6 (ICMPv6) header and redirected to the root of the tree. The root of the tree then decapsulates the ICMPv6 header and forwards the multicast frame down in the network. SMRF and ESMRF share similar characteristics. But with ESMRF, the multicast source can be any node in the RPL tree and not just the root node. The drawback of ESMRF is that all of the multicast traffic in the network is routed through the root node of the RPL tree.

In paper [6] multicast in RPL focus on routing issues and still many challenges has been left out. To create a multicast tree for effective routing author proposed a wireless shortest path heuristic (W-SPH) mechanism. The paper talks about increasing the reliability of the multicast, thus introducing proactive multicast forwarding with RPL (PMFR). Also compared the proposed results with MPL and ESMRF and achieved higher PDR and reduction in the energy

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consumption.

2.1. Research Gap

The following are the research gaps of different multicast protocols.

1. The size of the multicast address table and multicast routing table increases.
2. Packets are forwarded to nodes that are not interested in it.

3. Multicast Address Groups for Sensors

Each node can have multiple type of sensors like temperature, humidity...etc. If the publish subscribe mode is used for accessing data from different types of sensors, multicast address will help for grouping the sensors. In network a query must be forwarded to the nodes which has those sensors whose data is requested in the query.

A query is generally destined to one or more sensors. A multicast group address is reserved in the network for a group of sensors. When the base station queries any of the sensor in this sensor group, it should direct the query to the reserved multicast address.

For example, consider an IoT network with 3 types of nodes - Cameras, Smart-Lights and Thermometers in Table 1. The following table lists the various sensors each of these 3 devices supports.

IoT Devices	**Sensors**					
	Battery	**LED**	**Button**	**Image**	**Light**	**Temperature**
Camera	Y	Y	N	Y	N	N
Smart-Light	Y	Y	Y	N	Y	N
Thermometer	Y	Y	Y	N	N	Y

Table 1: Sensors supported on devices

Since all 3 devices has battery and LED sensors and 2 of the 3 have a button sensor, these 3 sensors can be grouped and assigned a multicast group address. Each of image, light and temperature sensor can be assigned an individual multicast group address.

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This scheme allows for multicast group addresses to be shared between sensors reducing the scale requirement of the multicast address and routing tables while still providing isolation between different sensors when needed.

Sub-sections 3.1 to 3.6 describe the various aspects of the solution proposed in this work. It includes

1. A new RPL sub-option to advertise sensor groups in the network is introduced.
2. Grouping sensors to multicast addresses and group advertisement.
3. Nodes joining and leaving groups based on the sensors associated with a group.
4. Multicast route lifetime management.
5. Multicast address compression to reduce the size of the DIO when advertising multicast groups.
6. Examples of different grouping schemes.

3.1. Multicast Sensor Group Advertisement

A sensor group [7] is a set of sensors that share the same multicast group address. Each sensor is assigned an integer value. A bitmap is used to represent a group of sensors where the bit associated with a sensor is set if the sensor is part of the group. While there is no restriction on how sensors can be grouped, the general thumb rule is to group sensors that are part of a particular node type. Two sensors that are not common to a node type are generally not grouped together. This ensures queries to sensors are not broadcasted to parts of the network that don't have a node supporting such a sensor.

In RPL, a DIO message (refer Figure 1) can be used to distribute this information to the entire network. A DIO message can carry several different sub-options. Each sub-option is meant to carry specific i nformation. To share the various multicast sensor groups, a new RPL sub-option is introduced (Figure 1 Darkened lines). Each multicast address is followed by a bitmap of sensors that are mapped to that multicast address. The size of the RPL sub-option will be based on the number of sensor groups in the network.

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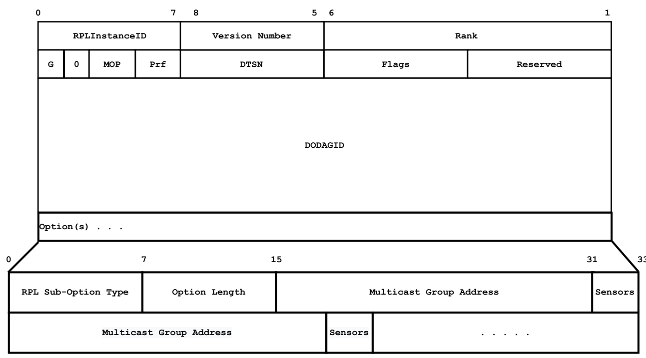

Figure 1: DIO - Message format [8] followed by DIO - new RPL sub option

The payload of the sub-option is a set of 'N' multicast group address + sensors associated with the address. Once the various sensor groups are mapped and multicast group address assigned, these must be advertised from the root of the network to all the nodes in the network.

3.2. Multicast Group Address and Sensors

The IPv6 multicast address that will be used as the destination address in the query packets. The address could be compressed to save space. The details on the compression scheme is described in Subsection 3.5.

The sensors is a bitmap representing all the sensors that will be queried using this mutlicast group address. The table lists a sample on the bits assigned for each sensor in table 2.

The root of the RPL network will advertise all the different groups via this sub-option. Each node in the DAG further propagates this information to the other nodes in the network ensuring the entire network is aware of the various multicast group addresses available and the sensors associated with each as shown in the Figure 2.

3.3. Multicast Sensor Group Join and Leave

When a node receives a DIO with this information for the first time, it looks for group addresses it should register to or 'join' to receive queries based on the

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Table 2: Bit map

Sensors	Bit
Battery	1
LED	2
Button	3
Image	4
Light	5
Temperature	6

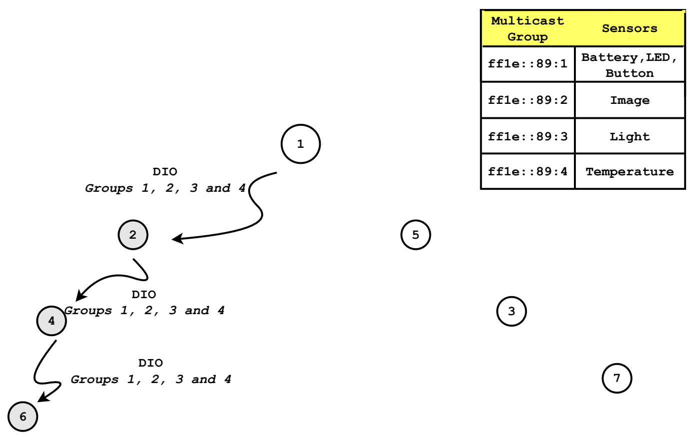

Figure 2: Multicast Group Advertisement

sensors it supports. To join a group, the existing RPL mechanism in storing mode is used where the node sends a DAO message to it's parent as shown in Figure 3.

When a node joins a group, it sends a DAO message to it's parent to indicate it's interest in the given group address using the RPL Target and Transit Information sub-options. When the parent receives the DAO, it adds the multicast group address in it's multicast routing table. This enables the parent to forward any packets destined to that multicast group address to it's child.

On receiving a DIO without a multicast group that the node has currently

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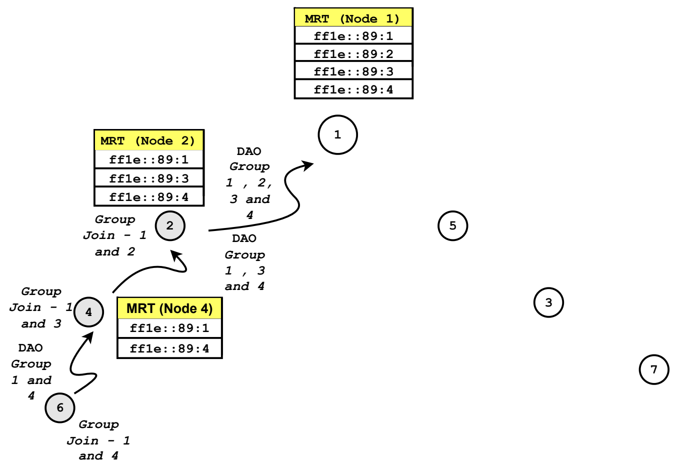

Figure 3: Multicast Sensor Group Join

joined as shown in Figure 4, it 'leaves' the group by sending a DAO to the parent with the RPL Target set to the multicast address it wants to leave and the lifetime set to 0 in the Transit Information sub-option. On receiving the DAO, the parent removes the multicast group address from it's multicast routing table as shown in Figure 5.

3.4. Multicast Route Refresh

All the multicast routes added in the upstream path when a node joins a multicast group have a lifetime. If a DAO with the same address and a new lifetime is not received before the end of the current lifetime, the routes are purged on the node.

To ensure the routes are not purged, a periodic timer is run on a node that has joined at least one multicast group. At the end of every cycle of this timer, DAOs for each multicast address present in the multicast address table of the node are sent to the parent with a refreshed lifetime. The parent updates the lifetime multicast route for each of these addresses with the new value.

By default, a lifetime of 180 seconds is assigned to each route. The periodic timer runs every 120 seconds to ensure a DAO is sent before the previous lifetime expires. Algorithm 1 mention about route refresh timer expire.

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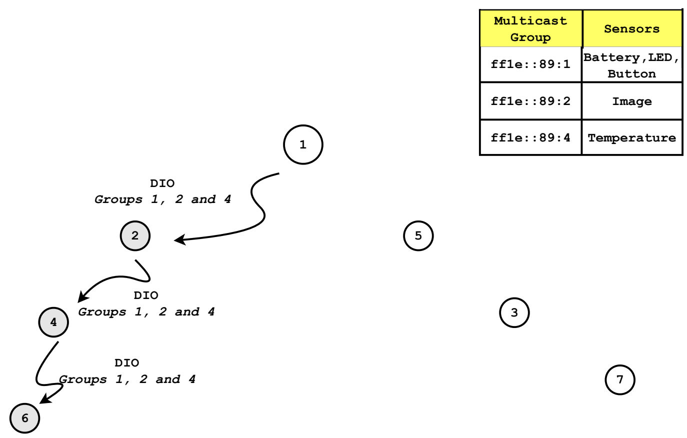

Figure 4: Multicast Sensor Group Update

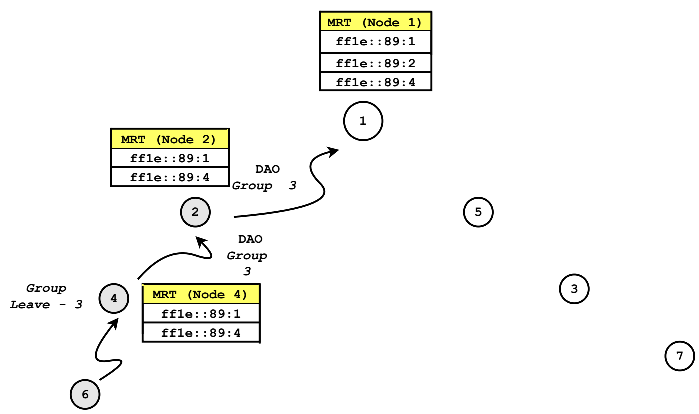

Figure 5: Multicast Sensor Group Leave

Algorithm 1 Route Refresh Timer Expire

Input: Multicast Address Table

Output: DAO Packets

Mcast-Addr-Record = HEAD(Mcast−Addr−Table)
while $Mcast - Addr - Record! = NULL$ **do**
  Mcast-Group-Addr = Mcast-Addr-Record.Group-Addr
  DAO.RPL−Target.Prefix = Mcast-Group-Addr
  DAO.Lifetime = Default-Mcast-Route-Lifetime
  Send(DAO)
end while

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3.5. Multicast Address Compression

The IPv6 address is 16 bytes long. Encoding a few of these addresses in the Group Advertisement message can cause the DIO message to grow rather large. To workaround this, the IPv6 addresses are compressed when possible.

Most of the IPv6 addresses have one or more consecutive bytes as 0. In this compression scheme as shown in Figure 6, if there are consecutive bytes of 0s in the addresses, they are omitted and not encoded in the message. Instead, a one byte metadata is prefixed with the address to indicate the compression details. The format of the metadata is described below.

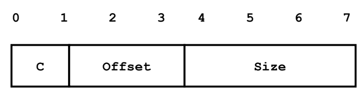

Figure 6: IPv6 Address Compression

1. C - Indicates if the IPv6 address following this header is actually compressed. A value of 1 indicates the addresses is compressed. 0 indicates the address is not compressed.
2. Offset - The byte in the IPv6 address where the compression starts.
3. Size - The number of consecutive bytes that is compressed.

Using a compression scheme significantly reduces the size of the DIO messages when advertising group addresses. Example of address compression in Figure 7 with this technique is as follows.

Multicast Address: ff1e:0000:0000:0000:0000:0000:0089:0001

3.6. New RPL sub-option payload with different grouping and compression schemes.

1. 6 Group Address, 6 Sensors - No compression

   In this scheme as shown in table 3, each of the 6 sensors is assigned its own group address and the IPv6 multicast group addresses are not compressed. A total of 108 bytes is required to share the group information in a DIO as shown in Figure 8.

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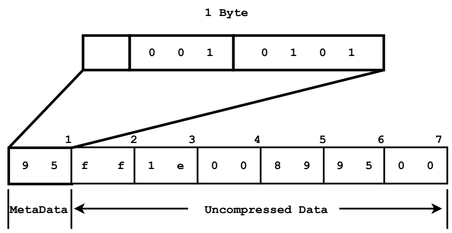

Figure 7: Metadata followed by Encoded data (Metadata + Uncompressed data)

Table 3: Multicast group address to sensor mapping

Group	**Multicast Address**	**Sensors**
G1	FF1E::89:1	Battery
G2	FF1E::89:2	LED
G3	FF1E::89:3	Button
G4	FF1E::89:4	Image
G5	FF1E::89:5	Light
G6	FF1E::89:6	Temperature

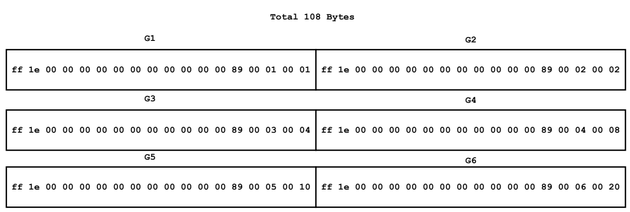

Figure 8: Encoded data

2. 6 Group Address, 6 Sensors - With compression

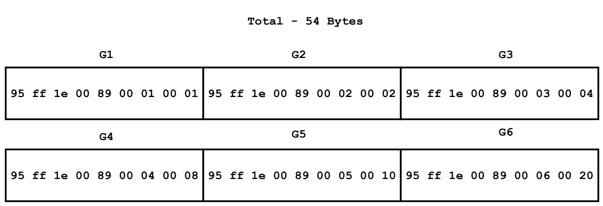

Figure 9: Encoded data

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Table 4: Multicast group address to sensor mapping

Group	Multicast Address	Sensors
G1	FF1E::89:1	Battery
G2	FF1E::89:2	LED
G3	FF1E::89:3	Button
G4	FF1E::89:4	Image
G5	FF1E::89:5	Light
G6	FF1E::89:6	Temperature

In this scheme as shown in table 4, each of the 6 sensors is assigned its own group address but the IPv6 multicast group addresses are compressed. With the multicast addresses used in the example and the resulting compression, a total of 54 bytes is required to share the group information in a DIO as shown in Figure 9.

3. 4 Group Address, 6 Sensors - With compression

Table 5: Multicast group address to sensor mapping

Group	Multicast Address	Sensors
G1	FF1E::89:1	Battery, LED, Button
G2	FF1E::89:2	Image
G3	FF1E::89:3	Light
G4	FF1E::89:4	Temperature

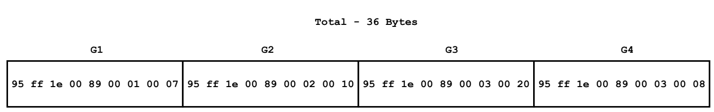

Figure 10: Encoded data

In this scheme as shown in Ftable 5, 3 of the sensors share the same group

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address and the other 3 are assigned their own group address. Thus a total of 4 group addresses is used for the same 6 sensors and the IPv6 multicast group address is compressed. A total of 36 bytes is required to share the group information in a DIO as shown in Figure 10.

From the 3 examples, it is obvious that using an address compression saves a lot of space in the DIO message when advertising the same group information. In addition, sharing the groups between sensors also reduces the number of multicast groups to advertise which in turn reduces the total size of the DIO when advertising the group information.

4. Results and Discussion

To compare the performance of group based technique with non-group based, two different topology is used. The first topology, Figure 11 uses 7 nodes. Node 1 acting as the base station. Node 2 and 3 acting as cameras. Node 4 and 5 acting as thermometers and Node 6 and 7 acting as light nodes. The second topology, Figure 12 uses 15 nodes. Node 1 acting as the base station. Node 2 to Node 6 acting as cameras. Node 7 to Node 11 acting as light nodes and Node 12 to Node 15 acting as thermometers.

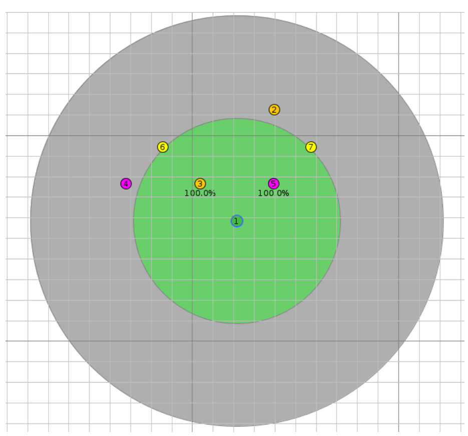

Figure 11: Two Level - Topology

Each of these nodes have the sensors as described in table 5.

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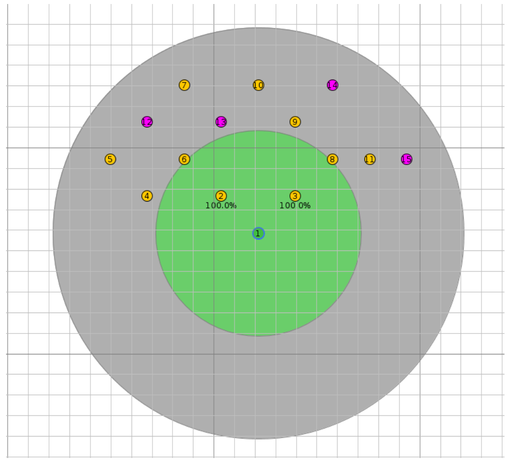

Figure 12: Three level - Topology

The multicast address groups to sensors are mapped as follows.

The base station sends a query every 5 seconds to all the scalar sensors. In addition to the scalar sensors, it also sends 2 blocks of the image query to the image sensor. The entire image query is transferred in 32 blocks. In the group based experiment, the base station advertises the multicast group addresses associated with each sensor and the nodes register to only those addresses that it or a downward node to which it is the parent is interested. In the non-group based experiment, the base station does not advertise any groups and each of the devices registers to all the multicast groups statically.

4.1. Experiment conducted using Cooja

Cooja is an open-source, java-based simulator available in Contiki Operating System, it is been known as a very suitable tool for IoT network development. Simulations are conducted in the cooja simulator by using Contiki OS. The proposed model is evaluated in comparison with the existing RPL protocol. Also considered Z1 mote for the experiment. Table 6 mention the simulation parameter.

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Table 6: Simulation Parameter

Simulation Parameter	Values
OS	ContikiOS 3.1
Radio model	Unit disk graph model
Mote type	Z1 Mote
Mode of operation	Storing mode
Network size	100 m x 100 m
Application Program	examples/er-rest-example
Simulation time	5mins

4.1.1. Two level topology

Figure 13 and Figure 14 show the number of queries successfully delivered to each node in both the group based and non group based techniques in the two level topology.

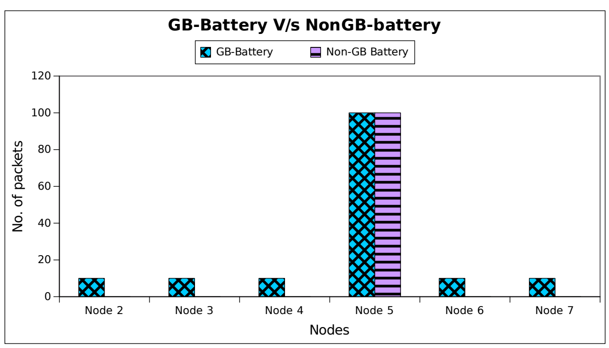

Figure 13: Queries delivered - Battery

Table 7 shows the percentage of improvement in the packet delivery ratio for group based technique over non group based technique.

4.1.2. Packet transmission - 2 level

The base station sends one query to each sensor every 10 seconds. A total of 100 queries are sent to each sensor in the simulation. Comparison has been

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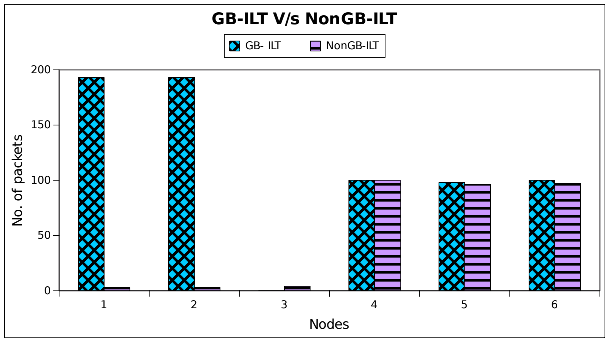

Figure 14: Queries delivered - Image, Light, Temperature

Sensors	Improvements %
Battery	83.33
Image	98.44
Light	0
Temperature	2.52

Table 7: PDR improvement with respect to RPL

made between NonGroup-based and Group-based group registration for packet transmission of packet is shown in Figure 15. Percentage improvement in Figure 16 with respect to NonGroup-based group registration is 35.03.

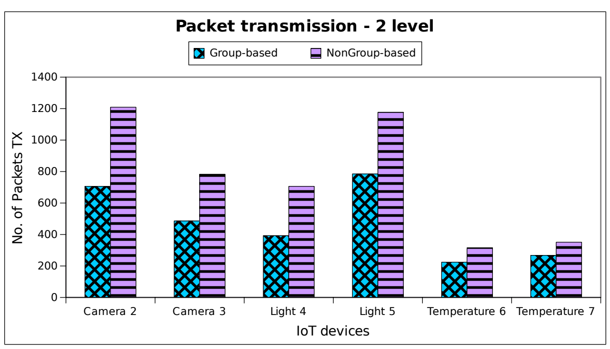

Figure 15: Packet transmission

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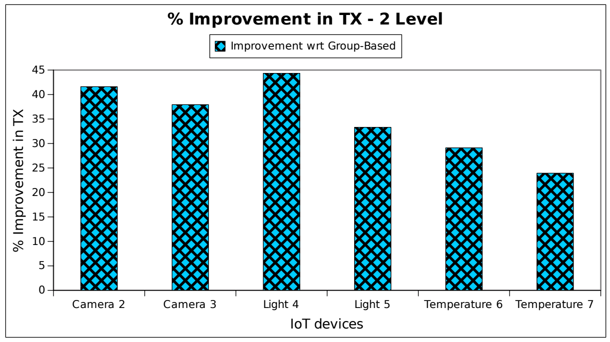

Figure 16: Improvement wrt Performance of packet transmission

4.1.3. Three level topology

Figure 17 and Figure 18 show the number of queries successfully delivered to each node in both the group based and non group based techniques in the three level topology.

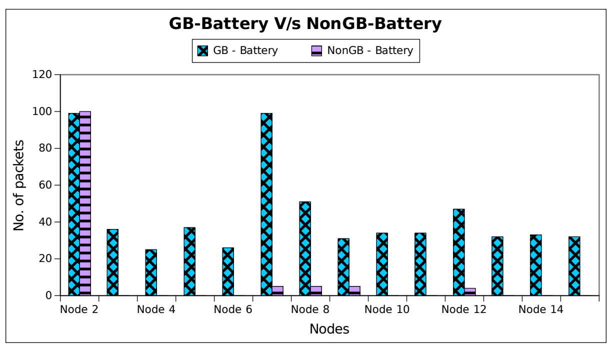

Figure 17: Queries delivered - Battery

Table 8 shows the percentage of improvement in the packet delivery ratio for group based technique over non group based technique.

4.1.4. Packet transmission - 3 level

The base station sends one query to each sensor every 10 seconds. A total of 100 queries are sent to each sensor in the simulation. Comparison has been made between NonGroup-based and Group-based group registration for packet transmission of packet is shown in Figure 19. Percentage improvement in Figure

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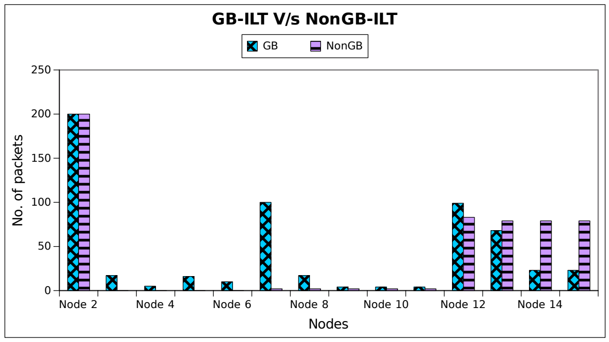

Figure 18: Queries delivered - Image, Light, Temperature

Sensors	Improvements %
Battery	89.86
Image	80
Light	67.24
Temperature	**-97.39**

Table 8: PDR improvement with respect to RPL

20 with respect to NonGroup-based group registration is 28.18.

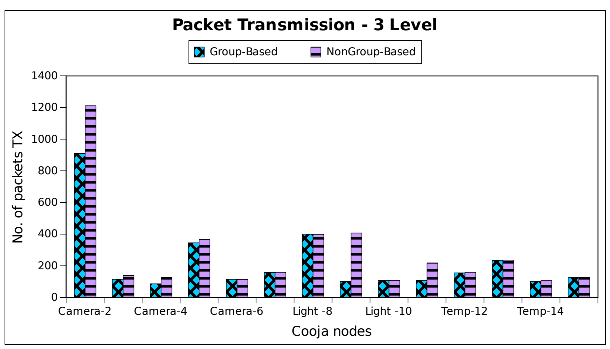

Figure 19: Packet transmission

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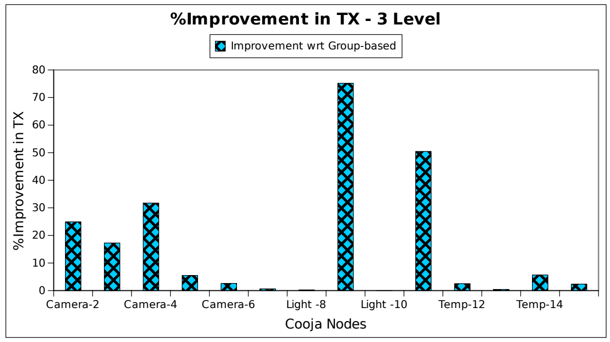

Figure 20: Improvement wrt Performance of packet transmission

4.2. Experiment conducted using FiT-IoT Lab

IoT-LAB [9] is a scientific tool used by many people doing research in various fields, addressing wireless communications, sensor networks, low power routing protocols, embedded and distributed applications, etc. Users are encouraged to share their experience, improvement ideas and results. Experiment is done in the LILLE site, France. M3 ARM-Cortex from the Lille site has been selected for the FIT IoT Lab testbed. The M3 node has an ARM M3-Cortex micro-controller, 64kB RAM, IEEE 802.15.4 radio AT86RF231, a rechargeable 3.7 V LiPo Battery, and several types of sensors.

The coordinates used for the nodes in FiT-IoT lab is the same as used in Cooja simulation.

4.2.1. Level 2 - FiTIoT Packet transmission

In Figure 21, shows the packet transmission using FiTIoT nodes. FiTIoT nodes provide better improvement in Transmission in Figure 22 wrt cooja Nodes is 43.54%.

4.2.2. Two level topology

Figure 23 and Figure 24 depict the packet delivery ratio for each type of sensor to all the interested nodes in a two level topology.

The results from the FiT-IoT lab show that the packet delivery ratio is better to all the nodes in the proposed group based technique when compared to the

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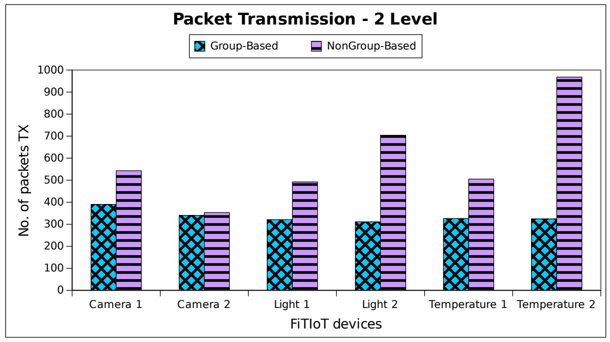

Figure 21: Performance of Packet Transmission

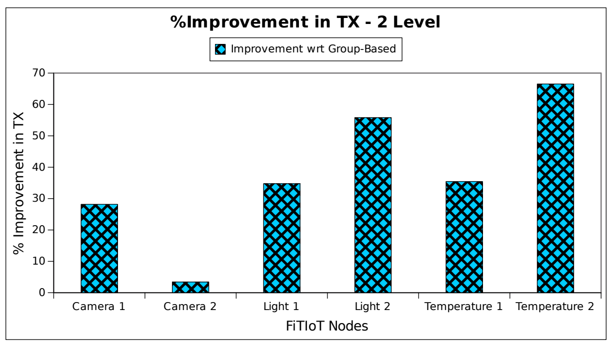

Figure 22: % Improvement of Packet Transmission

non group based method as seen in Table 9.

Sensors	Improvements %
Battery	4.244
Image	13.457
Light	16.609
Temperature	9.544

Table 9: PDR improvement with respect to RPL

4.2.3. Level 3 - FiTIoT Packet transmission

In 3 level, FiTIoT nodes perform packet transmission Figure 25 and also verify the improvement in Figure 26. The percentage improvement with respect

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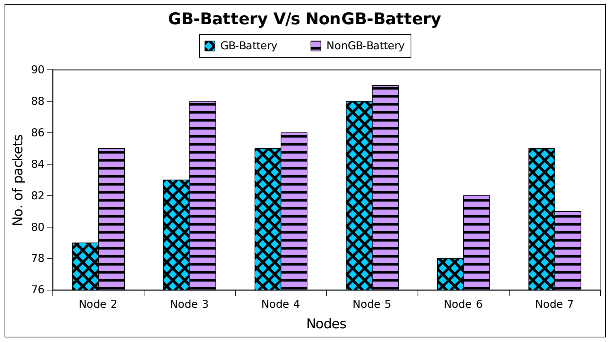

Figure 23: Queries delivered - Battery

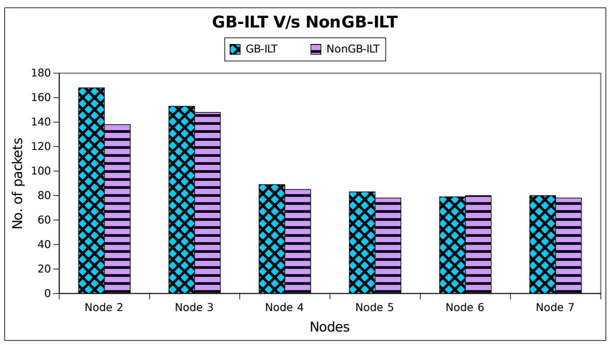

Figure 24: Queries delivered - Image, Light, Temperature

to NonGroup-based is 13.84.

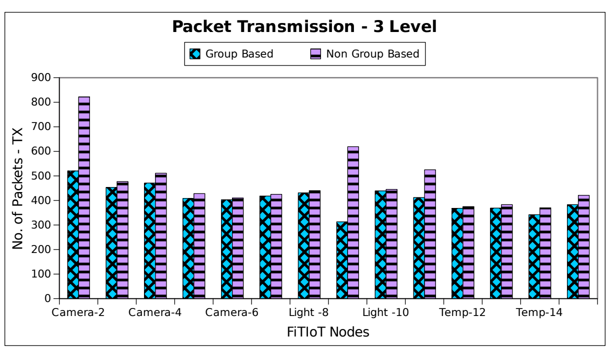

Figure 25: Packet transmission - 3 Level

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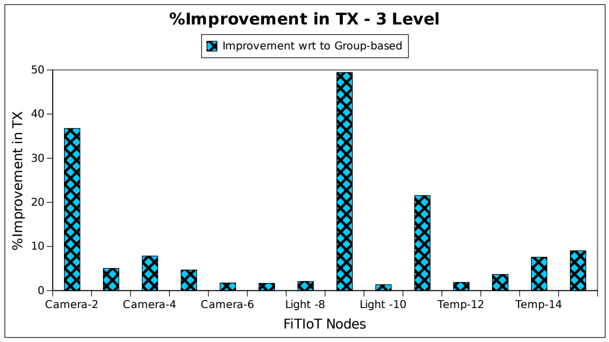

Figure 26: % Improvement wrt Group-based

4.2.4. Three level topology

Figure 27 and Figure 28 depict the packet delivery ratio for each type of sensor to all the interested nodes in a three level topology.

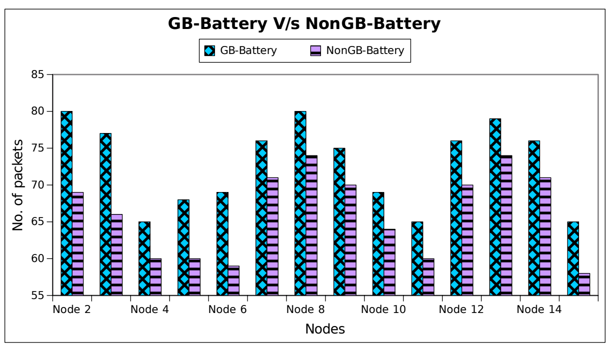

Figure 27: Queries delivered - Battery

The results from the FiT-IoT lab show that the packet delivery ratio is better to all the nodes in the proposed group based technique when compared to the non group based method as seen in Table 10.

5. Summary

In RPL based IoT networks, a popular workflow is for the base stations to query sensors deployed across the entire network. For efficient operations, these queries are directed to multicast addresses to ensure they get delivered to all

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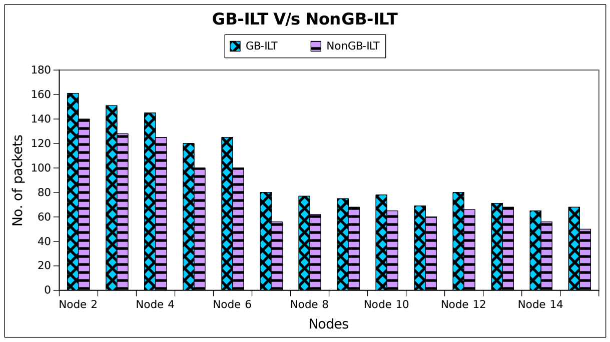

Figure 28: Queries delivered - Image, Light, Temperature

Sensors	Improvements %
Battery	25.34
Image	15.747
Light	17.704
Temperature	15.510

Table 10: PDR improvement with respect to RPL

the nodes on the network without the need of maintaining states at each node. But there isn't any good multicast group management schema today in RPL to manage the use of these multicast groups in the network. The proposed work attempts to define a simple multicast group management scheme to manage the various multicast addresses used when querying these sensors including group advertisement and registrations.

The results of the experiments on both Cooja and FiT IoT indicate that the group based technique offers better performance in terms of packet delivery ratio which in turn reduces the energy consumed to transmit the same of amount of data extending the lifetime of the network.

6. Conclusion

Introducing a way to advertise multicast group addresses in a RPL network helps interested nodes be aware of it and register for it if interested. The reg-

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istration can be further enhanced be also advertising the sensors targeted with each multicast address ensuring a node in the network only registers for it if it supports the sensor. This helps reduce the total number of multicast packets that is broadcast in the network thereby also conserving energy.

The association of multicast groups can be extended from just sensors to application based. Different address compression schemes can be used to ensure the payload in the DIO when advertising multicast address groups is as small as possible.

The proposed method are implemented on Contiki-3.1 and evaluated using FIT IoT-LAB testbed. The Testbed results improvement in the group based method when compared to normal RPL.

7. Acknowledgements

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