EasyChair Preprint

№ 5100

Routing Issues in Internet of Things (IoT): A Survey

Ghulam Ali Amiri

March 4, 2021

Routing Issues in Internet of Things (IoT): A Survey

GHULAM ALI AMIRI

Assistant Professor at Ghazni University, Afghanistan
Corresponding author: *ali.amiri0991@gmail.com*

Abstract: This paper states the routing issues in the Internet of Things (IoT). The main point of focus is especially routing protocols in IoT and wireless sensor networks (WSN). "Everything which is connected to the internet is alive", is going to be the new rule for future. Future is the Internet of Things (IoT), the world is changing every day with new technologies and inventions. Internet of Things (IoT) has known as a future scenario of technology in human life. IoT expands the concept of the Internet from a network of rather homogenous devices such as computers to a network of heterogeneous devices such as home appliances and the conventional network is mostly replacing with IoT. Devices are the main users of the IoT framework that an important part is IEEE 802.15.4, a standard which operating at the PHY layer and MAC layer of IoT devices. The IoT Ecosystem includes a large number of integrated heterogeneous low-power, low-cost devices, and secure connections are needed between them [15]. They communicate with each other to gather, share and forward the information in a multi-hop manner, this requires a complex routing between them. WSN, new technology in the IoT system comprised of a large collection of sensors, a mesh network can be used to individually gather data and send data through a router to the internet in an IoT system [6]. an enormous number of sensors are used and its growth is also fast, they are collecting the inexperienced data and transform it to the meaningful and useful information. considering the full usability of these devices and a huge number of them, produce routing challenges [16]. Routing in IoT is the most critical part because we are working with devices which they have restricted device resources. the optimum goal is to have enhanced routing protocols and efficient performance with such limited resource devices [15, 18].

Keywords: *Internet of Things (IoT); Wireless Sensor Networks(WSN); Routing protocol;*

1. INTRODUCTION

By the appearance of the Internet, people have been interconnected across geographical areas. Using embedded devices with sensors, they are able to interact with each other, objects and human as well. The sensors are able to capture and transmit the information they sensing from environments. Furthermore, the sensing, computing, and communication of information are a notable achievement in real time, automation and decision making systems. The nodes which are interconnected and built an embedded system, bringing two evolving technologies: wireless connectivity and sensors. These connected embedded systems are independent microcontroller-based computers that use sensors to collect data, process data, share and transmit information with or without human interaction. As billions of objects are connected to the internet, it's fundamental to an independent architecture that allows an easy connection, authentication, communication, and control. Kavin Ashton proposed the term "The Internet of Things has the potential to change the world, just as the Internet did. Maybe even more so" [1]. the IoT integrate various technologies together to build its vision. The integration of these technologies, along with Internet-based and context awareness services facilitate a dynamic platform for IoT. The IoT promises to build the globe, where all objects will be connected to the Internet and communicated with each other without/with minimum human interaction. The purpose of this research paper is to focus on the routing of the IoT. In fact, ''Internet of Things" semantically means ''a world-wide network of interconnected objects uniquely addressable, based on standard communication protocols" [14]. This implies a huge number of (heterogeneous) objects involved in the process.

2. INTERNET OF THINGS

As widely use of the IoT term and its usage areas, it's definition still in fuzzy [1]. The Internet of Things, on the other hand by its name, is comprised of two terms: Internet and Things. The term "Internet" states a networking based aspect of the IoT where the Internet serves as the central building block interconnecting every possible computing device in the world. The term "Things" states the devices, where these are used to sense the data and transmit to the processing nodes, most functions are doing here like computing and communicating of information. IoT is simply interconnected nodes include hosts and sensors, which used to sense, capture, compute, communicated and perform other related functions without or minimum human interaction. Based on another researcher the following is the definition of IoT is:

According to [1], "IoT stands for a worldwide network of interconnected objects uniquely addressable based on standard communication".

The IoT provide interconnected systems where the smart devices having sensors, are used to enhance the human relationship with the environment will be users of the internet.

3. ROUTING PROTOCOLS

In IoT routing protocols, there are various remarkable points which should be considered while selecting the IoT routing protocol. Lots of IoT routing protocols exist, each having a unique standard with a significant performance for Wireless Sensor Networks (WSNs) that can be used for IoT with few modifications for bandwidth and power consumption [6]. Actually routing for IoT is being selected based on IoT requirement and environment where more focus is on selecting a routing protocol uses less power and less bandwidth. As the environment is wireless Sensor Network, so power usage, security and bandwidth consumption are critical points. IoT suggests a wide number of applications in a different environment for enhancing human life qualities, so applications provide a vast amount of data and require security, storage, ownership, and routing configuration. The routing is the important part of an IoT network that is used to find the route. without route, there is no chance of sending/receiving to/from selected nodes. The routing issues become more challenging for low-power and lossy radio links, multi-hop mesh topologies, the battery supplied nodes and frequently changed network topologies.

3. 1. ROUTING PROTOCOLS IN WSN

In this part, I have to discuss some of the most popular routing protocols, especially in WSNs. routing protocols are classified in many different ways based on different circumstance. Routing protocols in this part will be explained into two sections: Network Structure and Protocols Operations [1, 17].

3.1.1. Network structure

attempted to optimize the network resources such as power consumption, bandwidth, traffic, load, delay. As network structure and its routing requirement, routing protocol will build accordingly to:

- **Flat routing protocols:** used in the network having a flat or horizontal structure as compared to hierarchical network structure each sensor node in the network plays equal role or importance at the same level, and collaborate with neighbor nodes to collect information. Routing information is distributed to other nodes without any organization or segmentation structure between them, all nodes are each other's peers. They enable the delivery of packets among other nodes through any available path without considering network hierarchy, distribution, and composition. The flat routing protocol is implemented in flat networks where each node routinely collects and distribute routing information by negotiating with its neighborhood. It's a good solution for homogeneous devices due to its low operational complexity and high efficiency.

- **Hierarchical routing:** it a procedure in which the network is splitting into many clusters and cluster head. It's designed for topologies having a hierarchical structure like corporate internet and corporate intranets connected with high backbones. Hierarchical routings are further subdivided into 2 categories: Tree based and Cluster based [6].

- **Location-based routing:** sensors node's locations are being found by the signal strength. If a node is located far away, the relative coordinates of nodes are being extracted from information exchanged between neighbor nodes. in this type, a node may get a decision to transmit route according to its localization and positions of other nodes in the network. Energy will be safe by putting unnecessary nodes into suspend or sleep.

3.1.2. Protocol Operations

routing protocols are categorized based on their functionalities and operations:

- **Negotiation based routing:** these protocols use high-level data descriptors called metadata in order to eliminate the redundant data transmission through negotiations. Based on the existence of resources the negotiation decision being done on participating nodes.

- **QoS based routing:** this type of routing protocol offers controlled bandwidth, delay, and other resources. Based on the quality of services routing protocol decision will take which type of traffic marks proper priority [8, 19].

- **Multipath routing:** in this scenario attempted to provide reliable network structure by creating multiple paths, load balance within them, handling the problem of fault tolerance and keep going even some paths are failed. Also, multipath routing protocol handles the QoS on configured paths for removing the traffic congestion [20].

- **Query-based routing:** as implies from its name, it uses request and reply mechanism. To discover route, request query will be sent to its neighbors and neighbors which having the proper answer or required data will reply back.

- **Energy-aware routing:** wireless Sensor Networks (WSN) comprise of many sensors with minimum battery power, power recharge or replacing in some cases is not possible, so such routing protocol is used to select the nodes with high energy resources and high network lifetime [18].

- **Context-aware routing:** context-aware means that the system continuously and autonomously monitors the situation and acts independently without the interaction from the users. The collected information will be used to specify the situation of an entity. Context-aware routing

protocols use contexts such as memory, processing power, location, and the speed of mobility in the routing process [4].

3. 2. Routing protocols in IOT

The routing protocol in IoT should support various communication methods [7]. such as:

- (multipoint-to-point) where from IoT devices to a central unit.
- (point-to-multipoint) where connection is required from a central unit to rest of the network.
- (point-to-point) where the direct connection among devices.

The routing protocol in IoT should consider the diversity or heterogeneity of devices and must be aware of device resources such memory and energy requirement, especially in resource-limited devices. Most of IoT devices are mobile or not fixed (e.g., robots, wearable healthcare devices) and network topology changes are occurring in time, so the IoT routing protocol must let the devices to move and connect to routing topology. Various IoT routing protocols exist, but I have to state some of popular of them here such as:

3.2.1. RPL – Ipv6

Routing Protocols for Low Power and Lossy Networks(LLNs), (LLNs) are formed up of many embedded devices with poor power, memory, and processing resources [2]. they are interconnected by a variety of links such as IEEE 802.15.4, Bluetooth, Low Power Wi-Fi, wired or other low power line connection. RPL use Trickle algorithm allows nodes in a lossy shared medium (e.g., low-power and lossy networks) to swap information in a highly robust, energy efficient, simple and scalable manner [3, 5]. RPL supports a mobile node to connect/disconnect to/from a routing topology, but the connection becomes extremely misleading. It has too large of a footprint for resource restrained devices and claims all devices in a network to run the same mode of operation, limiting heterogeneity. mobility is an unavoidable necessity in IoT situations, for which RPL currently provides unsatisfactory performance for nowadays IoT requirements. so, more development should be considered supporting context-aware routing and resource-limited devices. this protocol is built to deal with networks composed of restricted devices in energy, memory, computation capability, and low transmitted rate and more packet loss.

3.2.2. 6LoWPAN – Ipv6 over 802.15.4

The IPv6 protocol has a high overhead that makes it unstable for LLNs such as IEEE 802.15.4 networks [3]. for example, regarding the restricted space available for the MAC payload in an 802.15.4, the use of a 40 bytes IPv6 header length is not matching with 802.15.4 header length. IPv6 packets require an MTU size of 1280 bytes. The maximum size of a MAC layer frame in IEEE 802.15.4 is 127 bytes where 25 bytes are reserved for overhead and left 102 bytes for an IPv6 packet. If maximum security considered, then leaves just 81 bytes [9]. Also, the IPv6 header is 40 bytes, UDP header takes 8 bytes, and TCP header is 20 which added to the transport layer the situation become worse, there is a necessity of an adaption layer below IPv6 to provide fragmentation and reassembly so as to provide the MTU size required by IPv6 [10]. IEEE standard 802.15.4 designed to offer the fundamental lower network layers of a type of wireless personal area network (WPAN) which focuses on low-power, low-speed communication between devices. in contrast with other approaches like Wi-Fi, which offer more bandwidth and require more power. basically IEEE 802.15.4 standard state PHY and MAC layers for low-rate WPN. the PHY layer defines how the IEEE 802.15.4 sensors communicate using a wireless channel. there are almost 27 channels defined in the PHY layer, they are allocated to the different frequency band: the 868 MHz band, available in Europe, the 915 MHz band, available in the US, and the 2.4 GHz ISM band. 6LoWPAN merges the advanced version of the Internet Protocol (IPv6) with Low Power Wireless Personal Area Network (LoWPAN) allows the smallest devices with poor processing ability to transfer information in WSNs using Internet Protocol version 6 (IPv6), basic scenario shown in figure 1. 6LoWPAN standardized by IETF allows WSN with IP capability to transmit IPv6 packets across the IEEE 802.15.4 link layer on LoWPAN using adaption layer, by using such facility four basic header types are defined in 6LoWPAN: Mesh Header, Dispatch Header, Fragmentation Header, HC1 Header (IPv6 Header Compression).

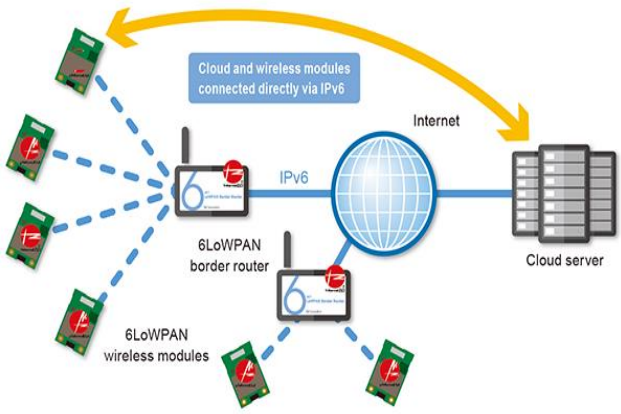

Figure 1

6LoWPAN routing protocols: due to the constrained resources of 6LoWPAN devices, the routing protocol should be intelligent of discovering and handling routing information between sensor nodes where they have limited resources available in terms of memory and processing unit consider to figure 2 we have routing in both network layer and adaptation layer [10]. AODV has been recognized as a great candidate for 6LoWPAN due to its simplicity in finding routes. However, some changes need to be done in AODV in order to adapt it into 6LoWPAN environments,

the two more routing protocols exist, such as LOAD and DYMO-low which are based on AODV. besides that, routing such as Hierarchical routing (HiLow) also be addressed in the following.

Application layer	Application layer
Transport layer	Transport layer
Network layer (IPv6)	Network layer(IPv6) **Routing**
6LoWPAN adaption layer **Routing**	6LoWPAN adaption layer
802.15.4 MAC layer	802.15.4 MAC layer
802.15.4 PHY layer	802.15.4 PHY layer
Mesh Under	**Route Over**

Figure 2

6LoWPAN ad-Hoc On-demand Distance Vector Routing (LOAD)

LOAD is defined to be operating on top of the adaptation layer instead of the transport layer. That is, it creates a mesh network topology underneath and unbeknownst to IPv6 network layer, IPv6 sees a 6LoWPAN as a single link. LOAD uses the broadcast message to discover the routes. for this reason, the Route Request (RREQ) message will be sent with destination broadcast address(0xffff) [10,11]. the destination sequence number is not using by LOAD to decrease the size of the control message and lighten the route discovery and convergence process. to guarantee of loop-free in the LoWPAN, only the destination of a route should generate the route reply (RREP) in reply, see figure 3. the nodes which are passing the route request to the destination should not respond with (RREP) if the LOAD repair a failed link during transmission only the destination can generate the RREP in reply, for this reason, the LOAD don't use the Gratuitous RREP [21]. The basic operations of LOAD are route discovery, managing data structures and maintaining local connections. For these operations, LOAD maintains the following two tables: the routing table and the route request table. The routing table stores route information such as destination, next hop node, and status. The route request table stores the temporary route information used in the route discovery process. There are two different types of 6LoWPAN devices: the reduced function device(RFD) and the full function device (FFD). LOAD should use only FFD for mesh routing. Thus, A FFD should implement the operations of LOAD and maintain the data structures of LOAD. the route cost such as link quality indicator (LQI) of the 6LoWPAN PHY layer in the routing decision in addition to the hop distance from the source to the destination is the routing metrics in LOAD. the threshold value is used to add LQI to a particular route, a number which defines routes are weak if their LQI is below that threshold value [11, 21]. LOAD assumes the use of either one of the two different addresses for routing: the EUI-64 address or the 16-bit short address of the 6LoWPAN device.

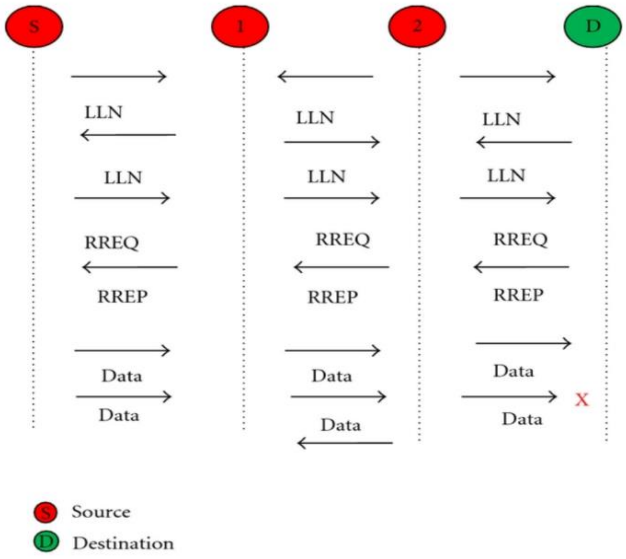

Figure 3

Dynamic MANET On-demand for 6LoWPAN Routing (DYMO-low)

DYMO performs route discovery and maintenance by using RREQ, RREP and RERR messages. while discovering routes, RREQ and RREP messages collect routing information from other nodes. the RREQ messages will be sent as IEEE 802.15.4 broadcast messages to all the next hop neighbors. Only the final destination should- reply back to the sender with an RREP in reply. addition to the routing cost such as the hop distance the Link quality (LQI) of IEEE 802.15.4 also used for selecting the best route. to maintain track of active links [10, 12]. The DYMO uses the Hello message to record the link availability and not using the local repair method in LOAD. DYMO-low is not layered on top of IP, but underneath it. It is an underlay. As such, it builds a mesh network topology of IEEE 802.15.4 devices that use single wireless interface each, underneath and unbeknownst to IP. such that IP sees the WPAN as a single link. All the 6LoWPAN devices on that WPAN are on the same IPv6 link, sharing the same IPv6 prefix. This is similar to how other technologies typically create complex structures underneath IP (e.g., Ethernet spanning tree bridges, token ring source routing, ATM, etc.). DYMO-low uses 16-bit link layer short address or IEEE64-bit extended address (EUI-64). DYMO-low and LOAD are same in most parts. but except that the 16-bits sequence numbers are used in DYMO-low to ensure loop freedom. Besides that, local repair and route cost accumulation that used in LOAD is no used as well in DYMO-low [12].

Hierarchical routing (HiLow)

6LoWPAN enables dynamic configuration of the 16-bit short address in the MAC layer, addition to the EUI-64 address. a 16-bit short address can be assigned to an IEEE 802.15.4 devices after finishing the association operation with its parent (or router) [10, 13]. this part describes the assignment of the dynamic address for the hierarchical routing. when an IEEE 802.15.4 device (or child) want to join a 6LoWPAN, it attempts to locate current 6LoWPAN by scanning procedures. If there is no 6LoWPAN in its personal operating space (POS), the child device becomes the initiator (or coordinator) of a new 6LoWPAN and assigns its short address by 0. Otherwise, the child device can find an existing neighbor device (or parent) of the existing 6LoWPAN and tries to associate with the parent at the MAC layer to receive a 16-bit short address [13]. A parent assigns a 16-bit short address to a child by the assignment scheme described in figure 4.

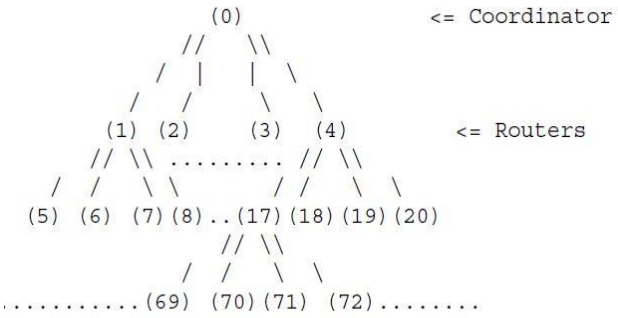

Figure 4

CONCLUSIONS

The popularity of wireless sensor networks (WSNs) has grown greatly over the last decade. Due to the improvement in sensor hardware technology and availability of cheap hardware, nowadays it becomes easy to append sensors to all the objects around us so that these devices will communicate with each other without human interference. Integration of these embedded devices into the Internet is challenging since they have properties that vary strongly from old internet devices, such as very limited energy, memory, and processing capabilities. However, the use of standardized protocols allows the integration of constrained devices in the IPv6 Internet. in this paper, I have surveyed IoT routing protocols from different aspects each having its goodness and failure. Routing in the internet of things is a new area of research and have lots of challenges with restriction, but a rapidly growing set of research results are available. In this paper, I presented a comprehensive survey of routing protocols in (IoT). They are using in Wireless sensor network (WSNs). Although many of these routing protocols look likely, there are still many challenges that need to be solved in the Internet of Things. Understanding routing in (WSNs) is one of the main challenges that IoT would face.

References

[1]. Amol Dhumane, Rajesh Prasad, Jayashree Prasad, *Routing Issues in Internet of Things: A Survey*, Proceedings of the International Multi Conference of Engineers and Computer Scientists 2016 Vol I,IMECS 2016, March 16 - 18, 2016, Hong Kong.

[2]. Anatol Badach, *A Literature Collection on Routing in the Internet of Things (IoT) with RPL*, DOI: 10.13140/RG.2.2.19771.72480.

[3]. Isam Ishaq*, David Carels, Girum K. Teklemariam, Jeroen Hoebeke, Floris Van den Abeele, Eli De Poorter, Ingrid Moerman and Piet Demeester, *IETF Standardization in the Field of the Internet of Things (IoT): A Survey*, Journal of Sensor and Actuator Networks ISSN 2224-2708

[4]. P. Temdee and R. Prasad, *Context-Aware Communication and Computing:Application for Smart Enviroment*, Springer Series in Wireless Technology, DOI 10.1007/978-3-319-59035-6_2

[5]. Amol Dhumane, Avinash Bagul, Parag Kulkarni, *A review on routing protocol for low power and lossy networks in IoT*, ISSN No: 2309-4893 International Journal of Advanced Engineering and Global Technology I Vol-03, Issue-12, December 2015

[6]. N.Jeb, V. Kamala, *A Survey on Routing Protocols for Internet of Things*, International Journal of Advanced Research in Science, Engineering and Technology, ISSN: 2350-0328.

[7]. Lotte Steenbrink Ausarbeitung, *Routing in the Internet of Things*, Faculty of Engineering and Computer Science Department of Computer Science, Hamburg University of Applied Science.

[8]. A. Dalvin Vinoth kumar1, Dr. L.Arockiam2, *Route Discovery Overhead Aware Routing Protocol for IoT to Enhance QoS*, International Conference on Computing Communication and Information Science (ICCCIS'16) PAPER ID:ICCCIS057144.

[9]. Abhik Chaudhuri, *Internet of Things, for Things, and by Things*, Identifiers: LCCN 2018017146| ISBN 9781138710443 (hbk) | ISBN 9781315200644 (ebook).

[10]. Gee Keng Ee*, Chee Kyun Ng, Nor Kamariah Noordin and Borhanuddin Mohd. *Ali, A Review of 6LoWPAN Routing Protocols*, Proceedings of the Asia-Pacific Advanced Network 2010 v. 30, p. 71-81. http://dx.doi.org/10.7125/APAN.30.11 ISSN 2227-3026.

[11]. Kim, K.; Daniel Park, S.; Montenegro, G.; Yoo, S.; Kushalnagar, N. *6LoWPAN Ad Hoc On-Demand Distance Vector Routing (LOAD)*, draft-daniel-6lowpan-load-adhoc-routing-03, 2007.

[12]. Kim, K.; Park, S.; Chakeres, I.; Perkins, C. *Dynamic MANET On-demand for 6LoWPAN (DYMO-low) Routing*, draft montenegro-6lowpan-dymo-low-routing-03, 2007.

[13]. Kim, K.; Yoo, S.; Park, J.; Daniel Park, S.; Lee, J. Hierarchical "*Routing over 6LoWPAN (HiLow)*", draft-deniel-6lowpanhilow-hierarchical-routing-00.txt, June 17, 2007

[14]. L. Atzori, A. Iera and G.Morabito, "*The internet of Things: A Survey",* vol.54, no.15, pp. 2787-2805, Oct 2010.

[15]. Ketan Devadiga, *IEEE 802.15.4 and the Internet of things*, Aalto University School of Science.

[16]. Amol Dhumane* and Dr. Rajesh Prasad**, *Routing Challenges in Internet of Things*, *Assistant Professor, Computer Engineering Department of NBN Sinhgad School of Engineering, Ambegaon(Bk), Pune, India.

[17]. Trang Tran Thi Thuy *Routing protocols in Internet of Things* trang.tran@aalto.fi

[18]. Behrang Barekataina, Shahrzad Dehghanib, Mohammad Pourzaferanic, *An Energy-Aware Routing Protocol for Wireless Sensor Networks Based on new combination of Genetic Algorithm & k-means*, Procedia Computer Science 72 (2015) 552 – 560, The Third Information Systems International Conference.

[19]. Pietiläinen, *Quality-of-Service Routing Antti*, Nokia Research Center P.O. Box 422, FIN-00045 NOKIA GROUP.

[20]. Mallikarjun Talwar, Routing techniques and protocols for internet of things: a survey, ISSN: 2250-0138

[21]. Hua-Mei Xin, Kun Yang, *Routing Protocols Analysis for Internet of Things*, 2015 2nd International Conference on Information Science and Control Engineering