Routing Protocols in IPv6 enabled LoWPAN: A Survey

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Abstract- 6LoWPAN consists of low power devices hat conform to IEEE 802.15.4 and uses the address scheme of IPV6. It is defined by IETF. It enables the integration of IPV6 and low power devices in a personal area network. We need this new technology in order to combine various low power heterogeneous networks and enable the embedded devices to communicate with the Internet based devices. The devices connected in the 6LoWPAN network need to route packets and transfer data and thus consider efficient routing as a major concern. Issues relating to the routing requirements and the various protocols in the area of routing in 6LoWPAN are presented in this survey.

Index Terms- Applications,IPv6, 6LoWPAN, Routing.

I. Introduction

6LoWPAN is an acronym of IPv6 over Low power Wireless Personal Area Networks[1].6LoWPAN technology is rapidly gaining popularity for its extensive applicability, ranging from healthcare to environmental monitoring. In order to provide more reliable and effective IPv6 connectivity on top of LoWPAN, the 6LoWPAN WG (Working Group) has defined some key technologies.

There are 6LoWPAN technology and its applications that discusses on possible technology that can enhance the energy efficiency of 6LoWPAN. One possible technology that is considered for combination with 6LoWPAN is the virtual multiple input and multiple output (V-MIMO) technology [10]. Since devices in 6LoWPAN are expected to be deployed in extremely large numbers and they are expected to have limited compute, display and input capabilities, it makes network management critical in 6LoWPAN [11]. The recent arrival of 6LoWPAN, an IPv6 variant for low-power wireless devices, allows for the development of IP-based applications for low-power wireless networks like sensor networks. As these networks often suffer from unreliable radio channels or frequent node failure, the question arises how 6LoWPAN-based applications can be hardened against such issues. Well-known concepts from the research domain of P2P networks can be applied for increasing the robustness of 6LoWPAN networks have been also recently discussed [16].

6LoWPAN devices are intended to be deployed in Ipv6 networks whose subnets that often will be physically disjunct and perhaps separated by large distances. A major advantage of exploiting the nearly inexhaustible address pool available in IPv6 is the ease with which true host-to-host communication can be realised. This however amplifies the importance of security in the network. It must be warranted with nearly 100% certainty that whenever a sensor node solicits or furnishes data to another node, that the solicited node be in fact that node from which the data is required, and just importantly, that the soliciting node be true node authorised to request the data.[18]
The 6LoWPAN concept originated from the idea that "the Internet Protocol could and should be applied even to the smallest devices," and that low-power devices with limited processing capabilities should be able to participate in the Internet of Things. The Internet of Things refers to uniquely identifiable objects (things) and their virtual representations in an Internet-like structure. In order to really benefit of such kind of integration the IPv6 addressing method and communication protocols adopted in the IoT must be modified to match the WSNs scenario. This adaptation has been standardized with the name of IPv6 over Low power Wireless Personal Area Networks (6LoWPAN).

The term Internet of Things was first used by Adam Baumgarten in 1999. The concept of the Internet of Things first became popular through the Auto-ID Center and related market analysts publication [2]. Internet of Things (IoT) is an integrated part of Future Internet and could be defined as a dynamic global network infrastructure with self configuring capabilities. These capabilities are based on standard and interoperable communication protocols where physical and virtual 'things' have identities, physical attributes, and virtual personalities and use intelligent interfaces, and are seamlessly integrated into the information network. The usage of IPV6 on wireless sensor networks can enable the integration of existing and new sensing applications with the internet. One key issue with the Internet of Things is the ability to rapidly create IoT applications[1][7].

6LowPAN enables the use of Service Oriented Architectures (SOAs) in WSN. The Internet Engineering Task Force (IETF) has defined the Constrained Application Protocol (CoAP), a web transfer protocol which provides several Hypertext Transfer Protocol (HTTP) functionalities, re-designed for constrained embedded devices. CoAP allows WSN applications to be built on top of Representational State Transfer (REST) architectures. This considerably eases the IoT application development and facilitates the integration of constrained devices with the Web.

Wireless sensor network (WSN) is one of the fastest growing segments in the ubiquitous networking today [4]. In order to morph WSN from personal area network (PAN) into low power personal area network (LoWPAN), IEEE standard 802.15.4 is introduced. A WSN consists of sensor nodes deployed over a geographical area for monitoring physical phenomena like temperature, humidity, vibrations, seismic events, and so on [3]. Typically, a sensor node is a tiny device that includes three basic components: a sensing subsystem for data acquisition from the physical surrounding environment, a processing subsystem for local data processing and storage, and a wireless communication subsystem for data transmission[5].

Whereas a wireless personal area network (WPAN for short) is a low-range wireless network which covers an area of only a few dozen metres. This sort of network is generally used for linking peripheral devices (like printers, cellphones, and home appliances) or a personal assistant (PDA) to a computer, or just two nearby computers, without using a hard-wired connection. There are several kinds of technology used for WPANs: The main WPAN technology is Bluetooth, 6LoWPAN is a simple low cost communication network that allows wireless connectivity in applications with limited power and relaxed throughput requirements as it provides IPv6 networking over IEEE 802.15.4 networks. It is formed by devices that are compatible with the IEEE 802.15.4 standard and characterized by short range, low bit rate, low power, low memory usage and low cost.

In this paper, a survey on routing in IPV6 enabled 6LoWPAN is conducted. This work classifies the routing protocols of 6LoWPAN based on various mobility issues and the heterogeneity of the networks.

This paper is divided into the following sections: Section II is the architecture of 6LoWPAN ,section III gives the classifications, Section IV gives the open issues and finally section V conclude paper.

II. ARCHITECTURE OF 6LOWPAN

6LowPAN working group mainly works on low power devices and the different types of LoWPANs are configured in some ratio to form the architecture of 6LoWPAN and thus the three types of LoWPANs are determined as discussed below and depicted in the Figure1

There are three types of 6LoWPANs : Ad-Hoc LoWPANs, Simple LoWPANs, and Extended LoWPANs. Ad-hoc LoWPANs are infrastructure less and not connected to the internet, a Simple LoWPANs is connected through one LoWPANs edge router to another Internet Protocol (IP) network. Extended LoWPANs have the LoWPANs consisting of multiple edge routers along with a backbone link in order to interconnect them [9]. The role of edge router is as it routes traffic data or video in and out of the LoWPANs. A LoWPAN consists of a number of nodes, which can play the role of a router or host, along with one or multiple edge routers.

One important term used with 6LoWPAN is the Neighbor discovery (ND), which facilitates the nodes to register with the edge router in order to provide efficient network operation. ND is the basic mechanism in 6LoWPAN and defines how routers and hosts communicate with each other on the same link. The IETF ROLL WG is currently in the final steps of the specification of RPL, a new routing protocol for low power and lossy networks (e.g. wireless sensor networks).

RPL may use layer two- and layer three-based mechanisms for neighbor reachability maintenance. Since layer two mechanisms may not always be available, RPL relies by default on the 6LoWPAN Neighbor Discovery, a version of the IPv6 Neighbor Discovery which is optimized for LLNs[12]. Nodes in the LoWPAN are free to move throughout the LoWPAN, between edge routers, and even between LoWPANs. 6LoWPAN standards enable the efficient use of IPv6 over low-rate, low-power wireless networks of simple embedded devices through an optimization of related protocols and adaptation layer

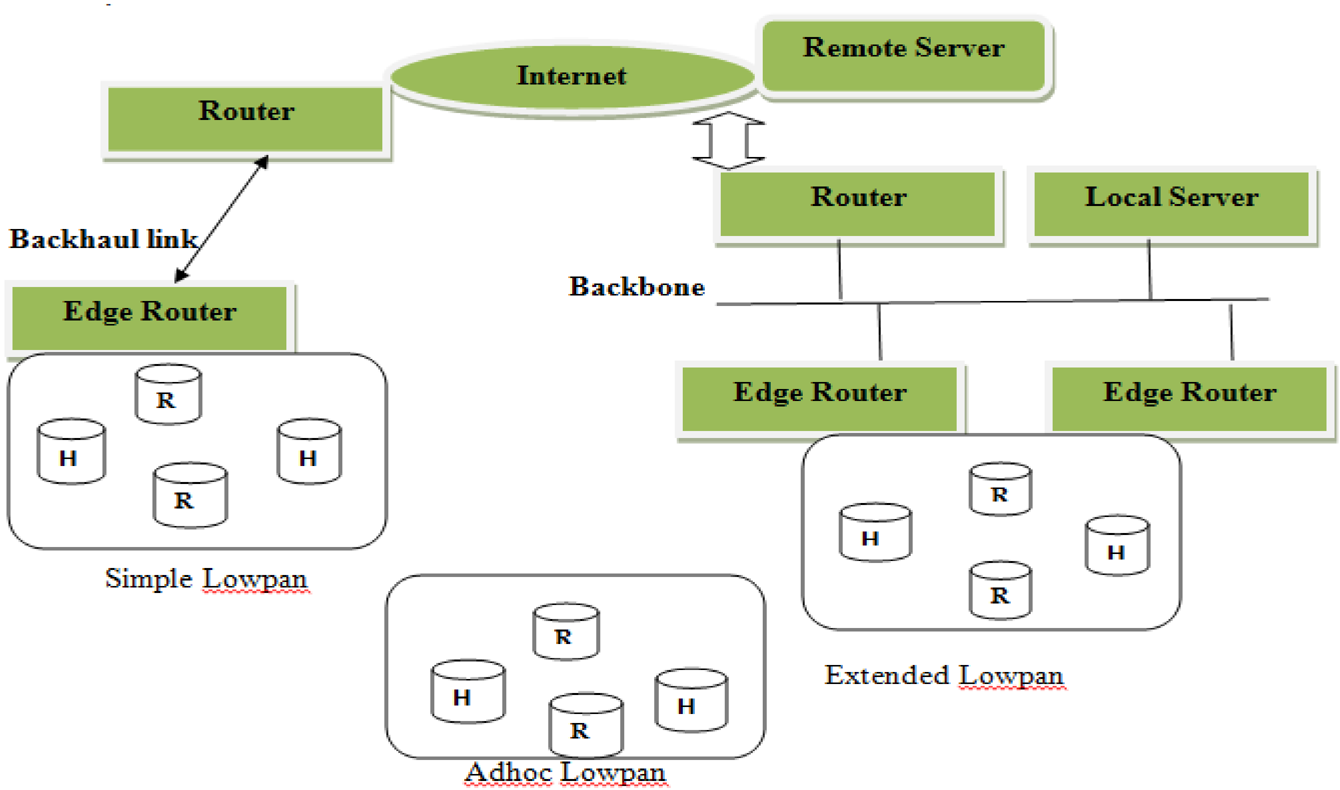

Figure 1 Architecture of 6lowpan

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Routing is the process of selecting paths in a network along which to send network traffic. Routing is performed for many kinds of networks, including the telephone network (circuit switching), electronic data networks (such as the Internet), and transportation networksIn packet switching networks, routing directs packet forwarding, the transit of logically addressed packets from their source toward their ultimate destination through intermediate nodes, typically hardware devices called routers, bridges, gateways, firewalls, or switches. General-purpose computers can also forward packets and perform routing, though they are not specialized hardware and may suffer from limited performance. The routing process usually directs forwarding on the basis of routing tables which maintain a record of the routes to various network destinations. Thus, constructing routing tables, which are held in the router's memory, is very important for efficient routing. Most routing algorithms use only one network path at a time, but multipath routing techniques enable the use of multiple alternative paths.There are four basic requirements for routing in 6Lowpan:(i)the node should support sleep mode for considering battery saving;(ii)generated overhead on data packets should be low;(iii)routing overhead should be lower;(iv)minimal computation and memory requirements.

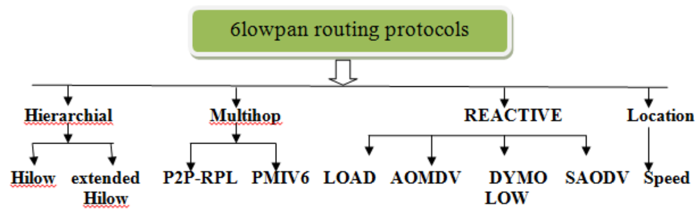
6LoWPAN has a broad range of applications as in Facility, Building and Home Automation, Personal Sports & Entertainment, Healthcare and Wellbeing, Asset Management, Advanced Metering Infrastructures, Environmental Monitoring ,Security and Safety Industrial Automation.[6] Transmission Control Protocol (TCP) was considered unsuitable for Low power and Lossy Networks (LLNs) due to the characteristics LLN devices (low computing power, strong energy constraint, etc.) and to the absence of IP layer on the network layer. Recently, the IPv6 over Low power Wireless Personal Area Networks (6LoWPANs) has been introduced as an adaptation layer for IPv6 over LLNs. Thanks to the 6LoWPAN layer and uIP (micro IP) protocol stack, TCP becomes more and more viable for LLNs. Moreover, TCP provides a reliable communication scheme between new small industrial devices [17].

The Mobility management is one of the most important research issues in 6LoWPAN, which is standardizing IP-based Wireless Sensor Networks (IP-WSN) architecture. Currently, IP-WSN is popularly recognized as a global sensor network infrastructure by combining IPv6 protocol with WSN[6]. IPv6 technology has obvious advantages compared to IPv4 in the address space, addressability, address autoconfiguration, security, mobility, QoS support, etc. However, IPv6 was originally designed for traditional IP networks. It needs improving according to the characteristics of WSNs, and then can be applied to WSNs and we also need to optimise the routing algorithms.

There are many issues relating to managing the addressing, mobility, routing protocols and their advanced versions and deciding the handover mechanisms in 6LOWPAN so many research activities have been carried out in order to deal with these issues but also many issues remain open and need to be addressed like security issues and so on.

III. CLASSIFICATION OF ROUTING PROTOCOLS IN 6LOWPAN

Depending on the topology of a 6LoWPAN and the application(s) running over it, different types of routing may be used. 6LoWPAN routing protocols should allow for dynamically adaptive topologies and mobile nodes. The routing protocols can be classified as follows:



HiLow [4] is a hierarchical routing algorithm well-known for the lightweight 16-bit short address allocation and routing mechanism. In HiLow, two types of nodes are defined: higher level nodes called parent nodes that are only represented by full-functional devices (FFDs) and lower level nodes called children nodes. Note that it is very important to reduce the path length for transmitting frames in order to reduce energy consumption and latency. In HILOW the number of hop counts is less compared to the existing hierarchical protocols. However, in the case in which the hop-counts in our scheme is the same as that in HiLow, latency will result due to the broadcasting of the “Hello” message to the forwarding nodes in the route path between the source node and the first ascendant node of the destination node.

HILOW routing protocol focuses on the address allocation method and routing mechanism. However the routing protocol doesn't address scenario where there is more than one potential parent node. If the child nodes attaches to the first responding parent when there is more than one potential parent than this could lead to bias or uneven distribution of child node. Bias association could impact the reliability and also shorten the life span of the network [3].

To overcome this problem a mechanism which uses current number of child node of potential parent was suggested. This mechanism displayed weakness when the responding parent node is having different depth or energy level or same number of current child. Thus HILOW routing protocol highlights the issues and suggests a mechanism which avoids a bias routing hierarchical tree set up. Sensor nodes in 6LoWPAN can distinguish each other and exchange packet after being assigned the 16 bits short address. HiLOW assumes that all the nodes know its own depth of the routing tree.

Each node in HiLOW [4] maintains a neighbor table which contains the information of the parent and children node. When a node loses an association with its parent, it should re-associate with its previous parent by utilizing the information in its neighbor table. In the case the association with the parent node is able to be recovered due to parent nodes battery drained, nodes mobility, malfunction and so on, the node should try to associate with new parent in its Personal Operation Space(POS).

Meanwhile if the current node realizes that the next-hop node regardless whether its child or parent node is not accessible for some reason, the node shall try to recover the path or to report this forwarding error to the source of the packet. Even though a route maintenance mechanism has been defined in HiLOW, the mechanism is seen as not sufficient.

An Extended Hierarchical Routing Over 6LoWPAN which extends HiLOW was presented by C.Nam et al[6]. in order to have better maintained routing tree. They suggested two additional fields to be added to the existing routing table of HiLOW namely, Neighbour_Replace]arent (NRP) and Neighbour_Added_Child (NAC). This NRP doesnot point to the current parent node but to another node which can be its parent if association to current parent fails. Meanwhile NAC refers to the newly added child node. HiLOW did not define a mechanism to handle a scenario where the child node detects more than one potential parent. A new mechanism which is able to overcome weakness displayed in previous mechanism and avoid bias child association was suggested. In this mechanism it is suggested that the new child node to be provided with two data, one is the depth of the potential parent node and secondly the average amount of power the potential parent node has [4].

RPL [5] is a routing protocol that organizes routers along a Destination Oriented Directed Acyclic Graph (DODAG), a category of Directed Acyclic Graph , rooted at the sink. The DODAG root initiates the DODAG formation by periodically originating DODAG Information Object (DIO) messages which it advertises via link-local.

The availability of paths from the sink to individual sensors are necessary in many scenarios, including industrial actuators and selective sensor queries. In order to address this lack, an RPL router that requires a path from the sink to itself must send a Destination Advertisement Object (DAO) message upwards along the DODAG all the way up to the root, which records and install this path. The DAO mechanism can be operated either in storing or in non-storing mode. In storing mode each router needs to store routing information in order to forward packets hop-by-hop.

RPL provides dog-legged paths for point to point (P2P) communication between arbitrary sensors in the network. P2P-RPL [6] allows routers to discover and establish path(s) to another router, based on a simple reactive mechanism. Essentially, when a router S needs to discover a path to another router D, router S originates a message similar in functionality to an AODV Route-Request. P2P-RPL uses the same mechanisms as basic RPL to form the DODAG. It introduces a new DIO option that specifies the address that should be discovered and records the traversed path.

Various protocol for 6LoWPAN mobile sensor node, named 6LoMSN, based on Proxy Mobile IPv6 (PMIPv6) [4] have been introduced. The conventional PMIPv6 standard supports only single-hop networks and cannot be applied to multihop-based 6LoWPAN. It does not support the mobility of 6LoMSNs and 6LoWPAN gateways, named 6LoGW, cannot detect the PAN attachment of the 6LoMSN. Therefore, the movement notification of a 6LoMSN in order to support its mobility in multihop-based 6LoWPAN environments is introduced. The attachment of 6LoMSNs reduces signalling costs over the wireless link by using router solicitation (RS) and router advertisement (RA) messages. In order to apply the single hop-based PMIPv6 protocol to multihop-based 6LoWPAN networks, a PAN attachment detection scheme for the 6LoMSNs is defined, using router solicitation (RS) and router advertisement (RA) messages, which is a modified lightweight neighbor discovery protocol.

Nodes in industrial scenarios often tend to be mobile. Active data flows may be in progress, which have to be held up while travelling around within the same prefix domain but also between different WSN. Mobility in IP based networks can be usually divided into two terms - micro and macro mobility. In 6LoWPAN micro mobility is considered as the mobility of a node in which the IPv6 prefix does not change. In contrast to that, macro mobility refers to mobility between networks, in which the IPv6 prefix changes.

In order to achieve a protocol that maximizes bandwidth efficiency in 6LoWPAN, the 6LoWPAN Ad-Hoc On-Demand Distance Vector Routing protocol (LOAD) has been proposed in It is a simplified on-demand routing protocol based on Ad-hoc On-Demand Distance (AODV). Besides that, Dynamic MANET On-demand for 6LoWPAN Routing (DYMO-low) is another 6LoWPAN routing protocol that based on DYMO. The significant feature in DYMO-low is it can support either 16-bit link layer short address or IEEE 64-bit extended address (EUI-64). To obtain a globally unique address for preventing address conflict, both AODV and LOAD use IEEE 64-bit address as devices' interface identifiers for building on demand multi-hop routing table.

LOAD [18] is an on demand routing protocol based on AODV and has been placed on top of the adaptation layer. It should run on the FFD nodes. There are certain routing metrics that this protocol needs as the route cost between the nodes and the number of hops. It also simplifies the routing table. The mechanisms of this protocol is that when a link breaks the upstream node tries to repair the link locally using the route discovery method and this protocol also saves some energy by using link layer acknowledgements and Hello messages. It uses the MAC layer acknowledgments for any data sent known as Link Layer Notification.

It uses the Route Request message(RREQ) in order to set up the route between two end points and then the other end gives a reply back in the form of the Route Reply(RREP) packet or message and then if the route cannot be set up then Route error(RERR) message is sent.

DYMO-low [19] is termed as Dynamic MANET On Demand for 6Lowpan routing and also depends on AODV and uses the same three messages as RREQ, RREP and RERR for route establishment .This protocol does not use the local repair mechanism but keep track of the connection using the HELLO message. It is placed on top of IP but this protocol cannot be used directly on the 6lowpan networks and thus another version DYMO-LOW is devised. It works on Link Layer and uses 16-bit link layer short address.

Speed [19] is a geographic routing algorithm and supports soft real time communication in large scale sensor networks. It includes certain features as avoiding route creation time, load balancing and flow shaping. The protocol provides three types of real-time communication services:

_ real-time unicast: a packet is sent to a specific node within the network which is identified by its geographic position and global network address;

_ real-time area-multicast: this service allows to send a data packet to all the nodes inside a destination area identified by its center position and radius;

_ real-time area-anycast: a packet is sent to at least one node inside an area specified by its center and radius.

S-AODV [21] is another routing protocol designed in order to adapt to the energy constraints in the 6LOWPAN networks. It introduces features as traffic reduction, power consumption and network lifetime extension and it also reduces the control information traffic and also optimise the performance of 6LOWPAN.

AOMDV [18] is defined as Ad-Hoc On Demand Distance Vector Routing With Multi-Path Scheme, it is another routing protocol that helps to find multipath routes during the route discovery. AOMDV compute multiple loop-free and link-disjoint paths in order to reduce the network overhead of route discovery. The AOMDV route discovery will find primary route and alternate route according to cost. When the primary route fail, then use the alternate route for continue transmit the data reducing the route discovery times.

In mesh-under routing [21] and forwarding are performed based on layer 2 addresses. The 6LoWPAN-working group has originally considered only the mesh-under approach to support routing. Mesh-under provides a virtual broadcast link to the IP protocol. In this case, the network layer can assume that all nodes within a subnet are directly reachable, hence, the IP model does not need to change. In the mesh-under approach, the routing and forwarding occur at data link layer or at 6LoWPAN adaptation layer.

In mesh-under approach, fragments can be delivered over multiple hops without requiring fragmentation and reassembly at each hop. Moreover, mesh-under also allows the use of multiple paths to deliver fragments for a given datagram. However, there are some significant drawbacks to this approach. Network diagnostic tools, such as trace route and some SNMP-based diagnostics, cannot be used in mesh-under approach since every node in the mesh is one hop away, from the viewpoint of IP.

In route-over approach, each radio hop is an IP hop. IP routing model works by separating the routing engine and forwarding engine into distinct functions. The routing function is responsible for maintaining the routing tables and the forwarding function examines the routing table to find the best next hop node to forward the packet

The main drawback of route-over approach is that it requires 6LoWPAN fragmentation and reassembly at every radio hop. As a consequence, the transmission of fragments of a given datagram to its final destination through multiple paths cannot be done. Note that fragmentation and reassemble occur at the 6LoWPAN adaptation layer and, therefore, only the first fragment carries the IP header.

IV. OPEN ISSUES

There are many issues regarding the routing in the 6LoWPAN networks which still need to be addressed and researched. The routing algorithms have been continuously modified into a better version but sill many issues pertaining to their optimization exits[8]. Many efforts are put into the area of forming the 6LoWPAN network and determining the potential parent node in such a network but still issue exist in determining some factors of finding the potential parent without much conflict. In the 6lowpan context some computation overhead exist while routing which needs to be handled and issues like using the 6lowpan network for centralised administration control still needs to be addressed.

V. CONCLUSION

In this paper we analysed the various routing requirements in 6LoWPAN networks and the also tried to understand the architecture of this network and tried to classify the various protocols in the routing area and we have found that many issues still need to be addressed in this area and the routing algorithms need to be optimised and the security need to be improved and also the various delays need to be minimised.

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