Networking Working Group A. Brandt
Internet-Draft Zensys, Inc.
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Home Automation Routing Requirement in Low Power and Lossy Networks
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Abstract

This document presents the home control and automation application specific requirements for Routing in Low power and Lossy Networks (RL2N). In a modern home, a high number of wireless devices are used for a wide set of purposes. Examples include lighting control modules, heating control panels, light sensors, temperature sensors, gas/water leak detector, motion detectors, video surveillance, healthcare systems and advanced remote controls. Because such

devices only cover a limited radio range, multi-hop routing is often required. Such devices are usually highly constrained in terms of resources such as battery and memory and operate in unstable environments. The aim of this document is to specify the routing requirements for networks comprising such constrained devices in a home network environment.

Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119 [RFC2119].

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1. Terminology

L2N: Low power and Lossy Network.

RL2N: Routing in Low power and Lossy Networks.

Access Point: The access point is an infrastructure device that connects the low power and lossy network system to the Internet, possibly via a customer premises local area network (LAN).

LAN: Local Area Network.

PAN: Personal Area Network. A geographically limited wireless network based on e.g. 802.15.4 or Z-Wave radio.

Channel: RF frequency band used to transmit a modulated signal carrying packets.

Downstream: Data direction traveling from the LAN to the PAN device.

Upstream: Data direction traveling from the PAN device to the LAN.

RF: Radio Frequency.

Sensor: A PAN device that measures data and/or detects an event.

HA: Home Automation.

2. Introduction

This document presents the home control and automation application specific requirements for Routing in Low power and Lossy Networks (RL2N). In a modern home, a high number of wireless devices are used for a wide set of purposes. Examples include lighting control modules, heating control panels, light sensors, temperature sensors, gas/water leak detector, motion detectors, video surveillance, healthcare systems and advanced remote controls. Basic home control modules such as wall switches and plug-in modules may be turned into an advanced home automation solution via the use of an IP-enabled application responding to events generated by wall switches, motion sensors, light sensors, rain sensors, and so on.

Because such devices only cover a limited radio range, multi-hop routing is often required. These devices are usually highly constrained in term of resources such as battery and memory and operate in unstable environments. Persons moving around in a house, opening or closing a door or starting a microwave oven affect

reception of weak radio signals. Reflection and absorption may cause a reliable connection to turn unreliable for a period of time and then being reusable again, thus the term "lossy".

Unlike other categories of RL2N, the connected home area is very much consumer-oriented. The implications on network nodes in this aspect, is that devices are very cost sensitive, which leads to resource-constrained environments having slow CPUs and small memory footprints. At the same time, nodes have to physically small which puts a limit to the physical size of the battery; and thus, the battery capacity. As a result, it is common for low-power sensor-style nodes to shut down radio and CPU resources for most of the time. Often, the radio uses almost just as much power for listening as for transmitting.

Section 3 describes a few typical use cases for home automation applications. Section 4 discusses the routing requirements for networks comprising such constrained devices in a home network environment. These requirements may be overlapping requirements derived from other application-specific requirements documents or as listed in [I-D.culler-rl2n-routing-reqs].

3. Home automation applications

Home automation applications represent a special segment of networked wireless devices with its unique set of requirements. To facilitate the requirements discussion in Section 4, this section lists a few typical use cases of home automation applications. New applications are being developed at a high pace and this section does not mean to be exhaustive. Most home automation applications tend to be running some kind of command/response protocol. The command may come from several places. For instance a lamp may be turned on, not only be a wall switch but also from a movement sensor.

3.1. Turning off the house

Using the direct analogy to an electronic car key, a house owner may activate the "leaving home" function from an electronic house key, mobile phone, etc. For the sake of visual impression, all lights should turn off at the same time. At least, it should appear to happen at the same time. A well-known problem in wireless home automation is the "popcorn effect": Lamps are turned on one at a time, at a rate so slow that it is clearly visible. Obviously, this mostly apply to very low bandwidth RF systems. Some existing home automation solutions use a clever mix of a "subnet groupcast" message with no acknowledgement and no forwarding before sending acknowledged singlecast messages to each lighting device. Broadcast packets

cannot be used for this since some lights should stay on. The light controller forms the groups and decides which light modules should receive "turn-off" or "turn-on" requests. Thus, traditional IP multicast cannot be used for such applications, since multicast relies on the recivers to subscribe to multicasted streams.

3.2. Moving a remote control around

A remote control is a typical example of a mobile device in a home automation network. An advanced remote control may be used for dimming the light in the dining room while eating and later on, turning up the music while doing the dishes in the kitchen. Reaction must appear to be instant (within a few hundred milliseconds) even when the remote control has moved to a new location. The remote control may be communicating to either a central home automation controller or directly to the lamps and the media center. The routing protocol MUST support multiple paths. The routing protocol MUST be able to locate a working path within 250ms, given that a working path exists and it has been used before.

3.3. Adding a new lamp module to the system

Small-size, low-cost modules may have no user interface except for a single button. Thus, an automated inclusion process is needed for light controllers to find new modules. The routing protocol MUST support re-discovery of neighbors when a new device is added to the network. The routing protocol MAY scan for neighbors on a frequent basis. This scanning process MUST NOT use significant network bandwidth resources.

3.4. Controlling battery operated window shades

In consumer premises, window shades are often battery-powered as there is no access to mains power over the windows. For battery conservation purposes, the receiver is sleeping most of the time. A home automation controller sending commands to window shades via RL2N resources will have no problems delivering the packet to the router, but the router will have to wait for some time before the command can be delivered to the window shades; e.g. up to 250ms.

3.5. Networked smoke alarm

Many smoke alarms are battery powered and at the same time mounted in a high place. Battery-powered safety devices should only be used for routing if no other alternatives exist. A smoke alarm with a drained battery does not provide a lot of safety. Also, it may be inconvenient to exchange battery in a smoke alarm. Finally, routing via battery-powered nodes may be very slow if they are sleeping most

of the time .

3.6. Remote video surveillance

Remote video surveillance is a fairly classic application for Home networking providing the ability for the end user to get a video stream from a Web Cam reached via the Internet, which can either be triggered by the end-user that has received an alarm from a movement sensor, smoke detector or that simply wants to check the home status via video. Note that in the former case, more than likely, there will be a form of inter-device communication: indeed, upon detecting some movement in the home, the movement sensor may send a request to the light controller to turn-on the lights, to the Web Cam to start a video stream that would then be directed to the end user (cell phone, PDA) via the Internet. By contrast with other application where for example a large number of L2N devices such as industrial sensors where the data would mainly be originated by sensor to a sink and vice versa, in such scenario there is a direct inter-device communication between L2N devices.

3.7. Healthcare

This section will be documented in further revision of this document.

3.8. Alarm systems

This section will be documented in further revision of this document.

4. Unique requirements of home automation applications

Home automation applications have a number of specific requirements related to the set of home networking applications and the perceived operation of the system.

4.1. Support of groupcast

Some home automation systems require low-level addressing of a group of nodes in the same subnet without any prior creation of multicast groups, simply carrying a list of recipients in the subnet.

The routing protocol MUST support multicast routing with various scopes: local subnet, all devices. In other words, the routing protocol MUST provide the ability to route a packet toward a single device (unicast), a set of devices (also referred to as "groupcast" in this document) or all devices (multicast) in the house.

The support of unicast, groupcast and multicast also has an

implication on the addressing scheme and are outside the scope of this document that focusses on the routing requirements aspects.

Note: with IP Multicast, signalling mechanisms are used by a receivers to join a group and the sender does not necessarily know the receivers of the group. What is required is the ability to address a group of receivers known by the sender even if the receivers do not need to know that they have been grouped by the sender (requesting each individual node to join a multicast group would be very impractical).

4.2. Node constrained Routing

Simple battery-powered nodes such as movement sensors on garage doors and rain meters may not be able to assist in routing. Depending on the node type, the node never listens at all, listens rarely or makes contact on demand to a pre-configured target node. Attempting to communicate to such nodes may require long time before getting a response.

Other battery-powered node may have the capability to participate to the routing protocol but it may be preferable to choose a (potentially longer) route via non battery powered devices or via battery powered that have more energy.

The routing protocol MUST support constrained based routing taking into account node properties (CPU, memory, level of energy, sleep intervals, safety/convenience of changing battery).

4.3. Support of Mobility

In a home environment, although the majority of devices are fixed devices, there is still a variety of mobile devices: for example a multi-purpose remote control is likely to move. Another example of mobile devices is wearable healthcare devices.

The routing protocol MUST provide mobility with convergence time within a few hundred milli-seconds.

4.4. Scalability

Looking at the number of wall switches, power outlets, sensor of various nature, video equipment and so on in a modern house, it seems quite realistic that hundreds of low power devices may form a home automation network in a fully populated "smart" home. Moving towards professional building automation, the number of such devices may be in the order of several thousands.

Thus the routing protocol MUST be highly scalable supporting a large number of devices (at least a few hundreds of devices).

4.5. Convergence Time

Home automation is clearly an L2N subject to various instability due to signal strength variation. Furthermore, as the number of (battery powered) devices increases, the probability of node failures also increases. In all cases, response time of the order of a few hundreds of milliseconds are required, implying that the routing protocol MUST converge (provide alternate routes upon link or node failure) within a few hundreds of milliseconds.

4.6. Manageability

The ability of the home network to support auto-configuration is of the utmost importance. Indeed, most end users will not have the expertise and the skills to perform advanced configuration and troubleshooting. Thus the routing protocol designed for home L2N MUST provide a set of features including 0 configuration of the routing protocol for a new node to be added to the network.

Furthermore, a misbehaving node MUST NOT have a global impact on the routing protocol. The routing protocol SHOULD support the ability to isolate a misbehaving node thus preserving the correct operation of overall network.

5. Traffic pattern

Depending on the philosophy of the home network, wall switches may be configured to directly control individual lamps or alternatively, all wall switches send control commands to a central lighting control computer which again sends out control commands to relevant light devices. In a distributed system, the traffic tends to be any-to-many. In a centralized system, it is a mix of any-to-one and one-to-many.

A centralized system may benefit from a tree topology routing strategy; having the central light controller close to the root.

A tree topology may prove inefficient for nodes in a distributed system. A direct path from sender to receiver may be significantly shorter than a path following the tree. A shorter path means lower latency and less air-time use in a wireless media. Thus, routers MUST provide efficient any-to-many routing and MUST also support any-to-any routing without having to transit via a central point (e.g. tree root) which would unavoidably lead to sub-optimal path in term

of latency and energy consumption.

6. Open issues

Other items to be addressed in further revisions of this document include:

* Load Balancing (Symmetrical and Asymmetrical),

* Security.

7. IANA Considerations

This document includes no request to IANA.

8. Security Considerations

TBD

9. Acknowledgements

10. References

10.1. Normative References

[RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, March 1997.

10.2. Informative References

[I-D.culler-rl2n-routing-reqs]
Vasseur, J. and D. Cullerot, "Routing Requirements for Low Power And Lossy Networks", draft-culler-rl2n-routing-reqs-01 (work in progress), July 2007.

Authors' Addresses

A Brandt
Zensys, Inc.
Emdrupvej 26
Copenhagen, Denmark DK-2100

Email: abr@zen-sys.com

JP Vasseur
Cisco Systems, Inc
1414 Massachusetts Avenue
Boxborough, MA 01719
USA

Email: jpv@cisco.com

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