Network Working Group   N. Kushalnagar
Internet-Draft   Intel Corp
Expires: January 13, 2006   G. Montenegro
                                              Microsoft Corporation
                                                      July 12, 2005

        6LoWPAN: Overview, Assumptions, Problem Statement and Goals
                     draft-ietf-6lowpan-problem-00.txt

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Abstract

   This document describes the assumptions, problem statement and goals
   for transmitting IP over IEEE 802.15.4 networks. The set of goals
   enumerated in this document form an initial set only. Additional
   goals may be found necessary over time and may be added to this
   document.

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1. Introduction

   Low-power wireless personal area networks (LoWPANs) comprise devices
   that conform to the IEEE 802.15.4-2003 standard by the IEEE
   [ieee802.15.4]. The IEEE 802.15.4 devices are characterized by short
   range, low bit rate, low power and low cost.

   This document gives an overview of LoWPANs and describes how they
   benefit from IP and IPv6 networking. It describes the requirements
   of LoWPANs with regards to IP layer and above. It spells out the
   underlying assumptions of IP for LoWPANs. Finally, it describes
   problems associated with enabling IP communication between devices in
   LoWPAN, and defines goals to address these in a prioritized manner.
   Admittedly, not all items on this list are necessarily appropriate
   tasks for the IETF. Nevertheless, they are documented here to give a
   general overview of the larger problem. This is useful both to
   structure work within the IETF as well as to understand better how to
   coordinate with external organizations.

1.1 Requirements notation

   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 [RFC2119].

2. Overview

   A LoWPAN is a simple low cost communication network that allows
   wireless connectivity in applications with limited power and relaxed
   throughput requirements. A LoWPAN typically includes devices that
   work together to connect the physical environment to real-world
   applications, e.g., wireless sensors. LoWPANs conform to the IEEE
   802.15.4-2003 standard. [ieee802.15.4].

   Some of the characteristics of LoWPANs are:

   1. Small packet size. Given that the maximum physical layer packet
       is 127 bytes, the resulting maximum frame size at the media
       access control layer is 102 octets. Link-layer security imposes
       further overhead, which in the maximum case (21 octets of
       overhead in the AES-CCM-128 case, versus 9 and 13 for AES-CCM-32
       and AES-CCM-64, respectively) leaves 81 octets for data packets.

   2. Support for both 16-bit short or IEEE 64-bit extended media
       access control addresses.

3. Low bandwidth. Data rates of 250 kbps, 40 kbps and 20 kbps for
    each of the currently defined physical layers (2.4 GHz, 915 MHz
    and 868 MHz, respectively).

4. Topologies include star and mesh operation.

5. Low power, typically battery operated.

6. Relatively low cost, typically associated with sensors, switches,
    etc. These drive some of the other characteristics such as low
    processing, low memory, etc. Numerical values for "low" have not
    been explicitly mentioned here as historically the costs tend to
    change over time.

7. Large number of devices expected to be deployed during the life-
    time of the technology. This number is expected to dwarf the
    number of deployed personal computers, for example.

8. Location of the devices are typically not predefined, thus these
    devices are deployed in an adhoc fashion. Furthermore, sometimes
    the location of these devices may not be easily accessible.

9. Devices within LoWPANs have a higher possibility of being
    unreliable due to variety of reasons: uncertain radio
    connectivity, battery drain, device lockups, physical tampering,
    etc.

The following sections take into account these characteristics in
describing the assumptions, problems statement and goals for
LoWPANs.

3. Assumptions

Given the small packet size of LoWPANs, this document presumes
applications typically send small amounts of data. However, the
protocols themselves do not restrict bulk data transfers.

LoWPANs as described in this document are based on IEEE 802.15.4-
2003. It is possible that the specification may undergo changes in
the future and may change some of the requirements mentioned above.

Some of these assumptions are based on the limited capabilities of
devices within LoWPANs. As devices become more powerful, and consume
less power, some of the requirements mentioned above may be somewhat
relaxed.

Nevertheless, not all devices in a LoWPAN are expected to be
extremely limited. This is true of so-called "Reduced Function

Devices" (RFDs), but not necessarily of "Full Function Devices"
(FFDs). These will also be present albeit in much smaller numbers,
and will typically have more resources and be mains powered.
Accordingly, FFDs will aid RFDs by providing functions such as
network coordination, packet forwarding, interfacing with other types
of networks, etc.

IP technology is assumed to provide the following benefits:

1. The pervasive nature of IP networks allows use of existing
    infrastructure.
2. IP based technologies already exist, are well known and proven to
    be working.
3. An admittedly non-technical but important consideration is that
    intellectual property conditions for IP networking technology are
    either more favorable or at least better understood than
    proprietary and newer solutions.

[4](). Problems

Based on the characteristics defined in the overview section, the
following sections elaborate on the main problems with IP for LoWPANs
Note that a common underlying goal is to reduce packet overhead,
bandwidth consumption, and processing requirements.

[4.1]() IP Connectivity

The requirement for IP connectivity within a LoWPAN is driven by the
following:

1. The many devices in a LoWPAN make network autoconfiguration and
    statelessness highly desirable. And for this, IPv6 has ready
    solutions.
2. The large number of devices poses the need for a large address
    space, well met by IPv6.
3. Given the limited packet size of LoWPANs, the IPv6 address format
    allows subsuming of IEEE 802.15.4 addresses if so desired.

However, given the limited packet size, headers for IPv6 and above
layers must be compressed whenever possible.

[4.2]() Topologies

LoWPANs must support various topologies including mesh and star.

Mesh topologies imply multi-hop routing. to a desired destination.
In this case, intermediate devices act as packet forwarders at the
link layer (akin to routers at the network layer). Typically these

are "full function devices" that have more capabilities in terms of
power, computation, etc. The requirements that apply on the chosen
routing protocol are:

1. Given the minimal packet size of LoWPANs, the routing protocol
    must impose low (or no) overhead on data packets, hopefully
    independently of the number of hops.
2. The routing protocols should have low routing overhead (less
    chatty) balanced with topology changes and power conservation.
3. The computation and memory requirements in the routing protocol
    should be minimal to satisfy low cost and low power
    characteristics. Thus storage and maintaining of large routing
    tables may be detrimental.

As with mesh topologies, star topologies include provisioning a
subset of devices with packet forwarding functionality. If, in
addition to IEEE 802.15.4, these devices use other kinds of network
interfaces such as ethernet, IEEE 802.11, etc., the goal is to
seamlessly integrate the networks built over those different
technologies. This, or course, is a primary motivation to use IP to
begin with.

4.3 Limited Packet Size

Applications within LoWPANs are expected to originate small packets.
Adding all layers for IP connectivity should still allow transmission
in one frame without incurring excessive fragmentation and
reassembly. Furthermore, protocols must be designed or chosen so
that the individual "control/protocol packets" fit within a single
802.15.4 frame.

4.4 Limited configuration and management

As alluded to above, devices within LoWPANs are expected to be
deployed in exceedingly large numbers. Additionally, they are
expected to have limited display and input capabilities.
Furthermore, the location of some of these devices may be hard to
access. As such, protocols designed for LoWPANs should have minimal
configuration, preferably work "out of the box", provide easy
bootstrapping, and should be able to self heal given the inherent
unreliable characteristic of these devices. The network management
should have less overhead yet be powerful to control dense deployment
of devices.

4.5 Service discovery

LoWPANs require simple service discovery network protocols to
discover, control and maintain services provided by devices. In some

cases, especially in dense deployments, abstraction of several nodes
to provide a service may be beneficial. In order to enable such
features, new protocols may have to be designed.

4.6 Security

Although IEEE 802.15.4 provides AES link layer security, a complete
end-to-end security is needed.

5. Goals

Goals mentioned here may point at relevant work that can be done
within the IETF (e.g., specification required to transmit IP, profile
of best practices for transmitting IP packets, and associated upper
level protocols, etc). It may also point at work to be done in other
standards bodies that exist or may exist in the future (e.g.,
desirable changes or profiles relevant to IEEE 802.15.4, W3C, etc).
When the goals fall under the IETF's purview, they serve to point out
what those efforts should strive to accomplish. Regardless of
whether they are pursued within one (or more) new (or existing)
working groups. When the goals do not fall under the purview of the
IETF, documenting them here serves as input to those other
organizations [liaison].

The following are the goals according to priority for LoWPANs:

1. As mentioned in the overview, the protocol data units may be as
    small 81 bytes. This is obviously far below the minimum IPv6
    packet size of 1280 octets, and in keeping with section 5 of the
    IPv6 specification [RFC2460], a fragmentation and reassembly
    adaptation layer must be provided at the layer below IP.

2. Given that in the worst case the maximum size available for
    transmitting IP packets over IEEE 802.15.4 frame is 81 octets,
    and that the IPv6 header is 40 octets long, (without optional
    headers), this leaves only 41 octets for upper-layer protocols,
    like UDP and TCP. UDP uses 8 octets in the header and TCP uses
    20 octets. This leaves 33 octets for data over UDP and 21 octets
    for data over TCP. Additionally, as pointed above, there is also
    a need for a fragmentation and reassembly layer, which will use
    even more octets leaving very few octets for data. Thus if one
    were to use the protocols as is, it would lead to excessive
    fragmentation and reassembly even when data packets are just 10s
    of octets long. This points at the need for header compression
    As there is much published and in-progress standardization work
    on header compression, this goal needs to investigate using
    existing header compression techniques and if necessary specify
    new ones.

3. [I-D.ietf-ipv6-rfc2462bis] specify methods for creating IPv6
    stateless address autoconfiguration. Stateless auto
    configuration has an advantage over stateful by having less
    configuration overhead on the hosts suitable for LoWPANs. The
    goal should specify a method to generate an "interface
    identifier" from the EUI-64 [EUI64] assigned to the IEEE 802.15.4
    device.

4. A routing protocol to support a multi-hop mesh network is
    necessary. There is much published work on adhoc multi hop
    routing for devices. Some examples include [RFC3561], [RFC3626],
    [RFC3684], all experimental. Also, these protocols are designed
    to use IP based addresses that have large overheads. For
    example, the AODV [RFC3561] routing protocol uses 48 octets for a
    route request based on IPv6 addressing. Given the packet size
    constraints, transmitting this packet without fragmentation and
    reassembly may be difficult. Thus care should be taken when
    using existing protocols or designing new protocols for routing
    so that the routing packets fit within a single IEEE 802.15.4
    frame.

5. One of the points of transmitting IPv6 packets, is to reuse
    existing protocols as much as possible. Network management
    functionality is critical for LoWPANs. [RFC3411] specifies
    SNMPv3 protocol operations. SNMP functionality may be translated
    "as is" to LoWPANs. However, further investigation is required.
    SNMPv3 may not be the best protocol for this task. Or it may be
    only after adapting it appropriately.

6. It may be the case that transmitting IP over IEEE 802.15.4 would
    become more beneficial if implemented in a "certain" way.
    Accordingly, implementation considerations are to be documented.

7. As header compression becomes more prevalent, overall performance
    will depend even more on efficiency of application protocols.
    Heavyweight protocols based on XML such as SOAP [SOAP], may not
    be suitable for LoWPANs. As such, more compact encodings (and
    perhaps protocols) may become necessary. The goal here is to
    specify or suggest modifications to existing protocols so that it
    is suitable for LoWPANs. Furthermore, application level
    interoperability specifications may also become necessary in the
    future and may thus be specified.

8. Security threats at different layers must be clearly understood
    and documented. Bootstrapping of devices into a secure network
    could also be considered given the location, limited display,
    high density and ad hoc deployment of devices.

6. IANA Considerations

This document contains no IANA considerations.

7. Security Considerations

TBD

8. Acknowledgements

Thanks to :

Geoff Mulligan

Soohong Daniel Park

Samita Chakrabarti

Brijesh Kumar

for their comments and help shaping this document.

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Authors' Addresses

   Nandakishore Kushalnagar
   Intel Corp

   Email: nandakishore.kushalnagar@intel.com

   Gabriel Montenegro
   Microsoft Corporation

   Email: gabriel_montenegro_2000@yahoo.com