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C. Bormann
Universitaet Bremen TZI
D. Sturek
Pacific Gas and Electric
Z. Shelby
Sensinode

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6LowApp: Problem Statement for 6LoWPAN and LLN Application Protocols

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Abstract

The 6LoWPAN and ROLL WGs are laying the groundwork to make the Wireless Embedded Internet a reality, but what application protocols will we use? Request-response protocols like HTTP are a poor fit to a communication model with battery-operated, mostly sleeping nodes. In addition, the usual data formats (both headers and body) are perceived to be too chatty for the 50-60 byte payloads possible in LoWPANs and to require too much code for the 8-bit and 16-bit processors dominating the Internet of Things. Still, it would be a mistake to start a new silo of application protocols that do not benefit from existing application area Internet experience.

This document provides a problem statement for possible work on of application protocols in 6LoWPAN networks or, more generally, in low-power, lossy networks, as well as some considerations for required related work.

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1. Problem Statement

The 6LoWPAN and ROLL WGs are laying the groundwork to make the Wireless Embedded Internet a reality, but what application protocols will we use with these networks?

6LoWPAN's low-power area networks (LoWPANs) and, more generally, ROLL's low-power lossy networks (LLNs) exhibit severe constraints on the bit rates achievable and the packet sizes that can be efficiently sent. Many (but not always all) nodes in these networks also are constrained in the energy they can expend for computing and communication, the memory available, and the code size that can be accommodated in each node. More generally speaking, there are many factors that play together to limit the per-node capabilities compared to today's typical Internet nodes.

(Moreover in most cases links in LoWPANs and LLNs are "lossy" by nature, thus experience high bit error ratios, making the communication sometimes challenging. The existing transport protocols used for reliability such as TCP may be too expensive to implement for LoWPAN nodes and may not perform well in lossy environments.)

The established application protocols for Internet applications may be a poor fit for LoWPANs and LLNs. For instance, request-response protocols like HTTP may require battery-operated, mostly sleeping nodes to be listening for requests much more frequently than their application processing requirements alone would need them to wake up.

In addition, some of the applications may require optimizations in terms of bandwidth usage; for example, the usual data formats (both headers and body) are perceived to be too chatty for the 50-60 byte payloads possible in LoWPANs. Their interpretation and generation may require too much code for the 8-bit and 16-bit processors dominating LoWPAN nodes.

Still, it would be a mistake to start a new silo of application protocols that do not benefit from existing application area Internet experience. A number of concepts well-established in the IETF application protocols, such as identifying resources by URIs, may transfer very well to LoWPANs.

This document provides a problem statement for possible work on application protocols in LoWPANs or, more generally, in low-power, lossy networks (LLNs), as well as some considerations for required related work. (When in doubt, it will focus on the requirements of LoWPANs, as these are more well-defined than the more general LLNs; we will therefore simply refer to both kinds of networks as LoWPANs.)

This problem statement builds on the 6LoWPAN problem statement [RFC4919]; familiarity with the 6LoWPAN suite of specifications [RFC4944] [I-D.ietf-6lowpan-nd] [I-D.ietf-6lowpan-hc] may be useful. Application requirements may also be hinted at in the various ROLL routing requirements documents [I-D.ietf-roll-indus-routing-reqs] [I-D.ietf-roll-building-routing-reqs] [RFC5548] [I-D.ietf-roll-home-routing-reqs] as well as the 6LoWPAN-specific routing requirements [I-D.ietf-6lowpan-routing-requirements].

2. Node and Network Characteristics

As mentioned in the introduction, the 6LowApp application protocol requirements are strongly influenced by the specific characteristics of LoWPAN nodes and networks. This section provides a quick summary of the most important differences to the Internet nodes that most of today's application protocols have been developed for, drawing heavily on [I-D.ietf-6lowpan-routing-requirements].

LoWPAN nodes may draw their power from primary batteries, forcing them to sleep most of the time (often with duty cycles of 0.1 % or lower) to achieve a reasonable battery lifetime (which may be identical to the node's lifetime!). Other, more "power-affluent" nodes may be mains-powered or, especially if carried around by humans, work from rechargeable batteries. Some devices may also make use of power scavenging where power can be harvested from solar or vibration energy; these nodes are designed for a long lifetime but still are power constrained and cannot afford to send long bursts of traffic.

Both transmission and reception are consuming significant power, where often keeping the receiver available for reception is nearly as expensive as actual reception or transmission. A mode of communication where LoWPAN nodes mostly decide on their own when to transmit is therefore more efficient.

The underlying radio technologies are often limited in the packet sizes they support [IEEE802.15.4]. While 6LoWPAN provides fragmentation and reassembly to support the much larger MTU required by IPv6 (1280 bytes), actually using this mechanism is expensive and significantly decreases packet delivery probability. This standard MTU is available if required for a specific activity, but most LoWPAN application protocols should attempt to get by with 50 to 60 byte packets (including some more or less compressed form of the IPv6 header, making this number hard to pin down).

Constrained LoWPAN nodes often only have a few KiB of RAM, and their code size tends to be limited to a value between 48 KiB and 128 KiB. Their processing speed may be limited by energy considerations to a few million instructions per second (which, at a duty cycle of 0.1 % or less, may mean a thousand instructions per second!).

Nodes may be rather limited in their abilities for user interaction, requiring special considerations for their initial configuration ("commissioning") including security configuration, bootstrapping, and fault management.

3. Application Protocols

A large number of applications will be enabled by LoWPAN and other LLN technologies becoming available for wide deployment. The four ROLL requirements documents cited above hint at possible use cases and their characteristics; additional use cases are documented in [I-D.ietf-6lowpan-usecases].

The whole point of using IP in LoWPANs is to let nodes in the LoWPANs interact directly with other IP-connected nodes. While software running on 6LoWPAN nodes will be highly application specific, the correspondent nodes will often be based on today's commodity systems; issues of integration with the software (including operating systems) running on these systems should be minimized. This appears to call for the use of existing, widely deployed transport protocols such as UDP and TCP.

Today's LoWPAN nodes typically use UDP exclusively. TCP is complex enough to be a concern for some very limited systems; also, its reaction to loss as a congestion signal may not be appropriate for lossy LoWPAN networks, in particular where some real-time requirements are involved.

On the other hand, some form of acknowledged and numbered packet delivery is required for lossy networks. So far, application developers have resorted to using UDP with application specified sequence numbers, transmission timeouts and retries. Not having TCP available limits the availability of many established application protocols that depend on TCP or at least are implemented using TCP in correspondent nodes today.

The use of UDP and the limited packet sizes efficiently supported by LoWPANs make relatively verbose protocols such as HTTP less desirable. On the other hand, key principles of the web such as resource identifiers (URIs), content types (MIME), statelessness, proxy support etc. are most desirable.

Possible additional elements from solution space include:

Connection splitting at border devices. The LoWPAN architecture calls for relatively powerful devices at the border of the constrained networks ("edge routers"). These could include PEP functions [RFC3135] including TCP splitting, possibly using a limited/specialized form of TCP for the connection segment within the LoWPAN.

Full support for Web services (not very likely of the WS-* variety). The objective would be to enable deployment of simple

web-accessible resources (possibly even including human-readable web pages) for small footprint devices interfaced with a compact exchange protocol. Investigate deployment of a small footprint condensed HTTP-like protocol. Investigate use of tokenized XML in addition to condensed HTTP.

SNMP. The objective would be to enable SNMP services, again for small footprint devices. Investigate deployment of a compact version of SNMP limited to small UDP packets. Ensure that security services are available for the compact version of SNMP, even if it must be deployed using UDP. More generally, many nodes will not have resources for implementing both SNMP and HTTP; a way to obtain the benefits of both in one implementation would be preferable. (The point that these two protocols address different communities and are even handled in two separate areas in the IETF is well taken.)

4. Supporting Protocols

Supporting protocols are needed for commissioning (including security, see next section) and bootstrapping.

In order to simplify commissioning (plug-and-play operation) and bootstrapping, a service discovery protocol (such as SLP) optimized for LoWPAN usage is likely to be employed. Possible elements from solution space include:

A Service Discovery repository for devices which sleep most of the time. (The design space might include a centralized repository, e.g. on the Edge Router, as well as decentralised repositories for the service discovery protocol.)

Application specified fields in the service discovery repository and in the search protocol that enable a device with specific application defined characteristics to be selectively discovered by other devices in the network.

An ability to set the scope of "the network" to produce bounded service discovery requests matching network resource capabilities. (The scope might not be limited to the LoWPAN, but might contain hosts from the networks the edge routers are attached to.

A protocol that is able to differentiate between types of services, such as source, processing, sink as well as commissioning and bootstrapping services and possibly connects matching services to each other.

A rich protocol for service discovery requests that wherever possible tries to limit resource usage of the network to support the request while supplying targeted responses. Specifically, this would obviate the need for multicast and would introduce some binary tags etc. rather than string-based descriptions which require too much code to parse and are too chatty.

5. Related Standardization Activities

6LowApp will need to interface with various other standardization efforts, such as

ISA SP100.11a

the ZigBee/IP effort

the Smart Energy standardization at the IEC

UCA International (and OpenSG)

Society of Automotive Engineers (SAE)

ETSI Machine-to-Machine (M2M) Technical Committee (TC)

Efficient XML Interchange (EXI) at the W3C

New EU smart grid standardization effort

Open Geospatial Consortium (SWE)

Device Profile Web Services (DPWS)

BACnet: A Data Communication Protocol for Building Automation and Control Networks (ANSI/ASHRAE 135-2008, EN ISO16484-5)

As an example, consider the needs of "Smart Grid" Home Area Networking (HAN) Applications. For Smart Grid HAN applications, getting IP connectivity to devices such as thermostats, in-home displays, load control wall plugs, refrigerators and plug-in electric vehicles solves the problem of introducing these devices onto the internet. To fully realize application deployment the following features are needed:

A basic framework for reliability as is provided by TCP for most existing application protocols (see Application Protocols above).

A basic framework for service discovery (see Supporting Protocols above).

Security (see Security Considerations below).

Roaming support. Nodes will need to bootstrap in different LoWPANs, e.g., plug-in electric vehicles (PEVs) will need the ability to roam between networks. It is not clear that MobileIP will solve even part of this problem as there may not be a logical

place to hold a forwarding registry. There will be relatively many such devices; it is not clear that assuming a static global IP address per car is the right approach. 6LowApp should consider the ZigBee/HomePlug MRD Use Cases, the SAE use cases around PEVs and consider how roaming devices can be accommocated. Also, there is an IEC group (TC 22, Task Group 3) working on a similar solution so that work should be reviewed for requirements.

In addition, this is an area where the use of intermediate processing nodes -- sometimes referred to as ALG (Application Layer Gateways -- providing enhanced security, local data processing and storage, provisioning, etc. may be of particular interest.

(Another related area is future applications in support of the smart grid, for example "sub-station automation" where new IP sensors and actuators are being developed and for which one may consider the interconnection of existing legacy applications to IP-based applications, beyond IP connectivity.)

In addition to a compact, efficient application protocol, the content carried in such a protocol is equally important. XML is not suitable for use with the limited payload sizes available on LoWPANs and for parsing on simple embedded devices. Relevant standardization efforts are being performed which enable the encoding of XML in suitable formats. For example at the W3C, the Efficient XML Interchange (EXI) format has been developed, allowing for XML to be represented in a very compact and machine-parsable format.

6. Security Considerations

Many LoWPAN applications have strong security requirements. Some of these will need to be solved at the underlying link layer (6LoWPAN devices usually have good support for confidentiality and authentication), many will require solutions at the application layer (possibly using transport layer security). Most devices will benefit from some synergy between the key management mechanisms at these two layers; in any case these mechanisms must be appropriate for highly constrained devices.

Possible elements from solution space include:

EAP is well-known in the wireless world and appears to be a good framework to standardize on. However, work is needed on open security methods applicable to small footprint devices.

For applications wanting to use certificates, enhancements to the current usage of certificates (X.509) and IEEE 802.1X may be needed to support small footprint devices.

7. Acknowledgements

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Authors' Addresses

Carsten Bormann
Universitaet Bremen TZI
Postfach 330440
Bremen D-28359
Germany

Phone: +49-421-218-63921
Fax: +49-421-218-7000
Email: cabo@tzi.org

Don Sturek
Consultant, Pacific Gas and Electric
77 Beale Street
San Francisco, CA
USA

Phone: +1-619-504-3615
Email: d.sturek@att.net

Zach Shelby
Sensinode
Kidekuja 2
Vuokatti 88600
FINLAND

Phone: +358407796297
Email: zach@sensinode.com