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Li Zhao

Pascal Thubert

Lele Zhang

Chuanwei Li

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NOVEL DATA AGGREGATION IN LOW-POWER AND LOSSY NETWORKS

AUTHORS:
Li Zhao
Pascal Thubert
Lele Zhang
Chuanwei Li

ABSTRACT

With the continued growth of the Internet of Things (IoT) different types of Low-Power and Lossy Networks (LLNs) have emerged. Such networks may face a number of challenges including, for example, link bottlenecks. To address these challenges techniques are presented herein that support a new method of aggregating data packets in a LLN without incurring a performance decrease. Aspects of the techniques presented herein leverage fragmenting of aggregated data packets (to avoid instances of a larger frame being dropped) and enhance the Media Access Control (MAC) layer (so that frames are grouped with just a single acknowledgement for all of the frames).

DETAILED DESCRIPTION

With the continued growth of the IoT different types of LLNs have emerged. As one example, a connected-grid mesh (CG-Mesh) network may support, for example, IoT applications such as, possibly among other things, a smart grid in Advanced Metering Infrastructure (AMI) networks, a distribution automation (DA) gateway in electrical power delivery networks, etc. As another example, the Wireless Smart Utility Networks (Wi-SUN) alliance promotes a standards-based interoperable wireless solution for IoT.

A CG-Mesh network and a Wi-SUN environment are multiple hop mesh networks. Figure 1, below, provides a high-level depiction of such a network.

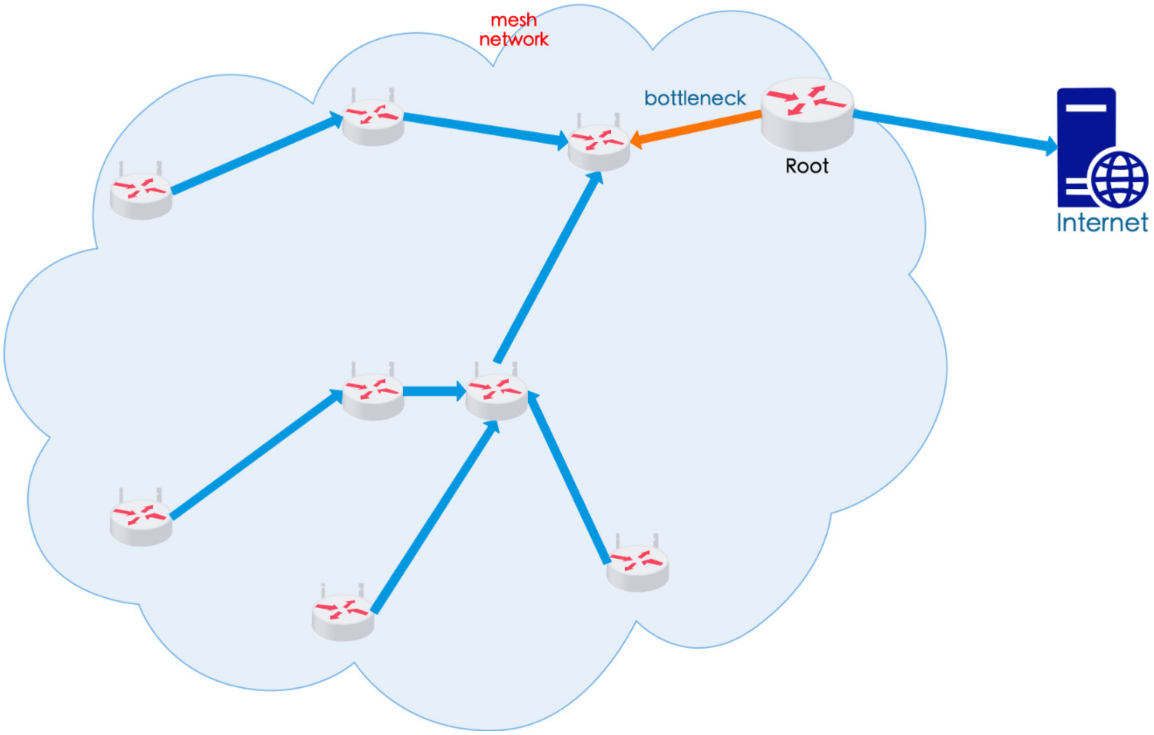

Figure 1: Multiple Hop Mesh Network

As illustrated in Figure 1, above, a Root node operates as the border router of the mesh network to interconnect with the Internet. A Routing Protocol for LLN (RPL) may be employed as the basis of the network routing, and a source routing header may be used (e.g., to identify a path) for downward data transmission. A network of the type as illustrated and described above may face a number of challenges or problems.

As a first example of such problems, the link between the shallow hop nodes and the root is clearly a bottleneck of the entire network because all ingress and egress data must pass through it. In some cases, Internet Protocol (IP) headers such as a source routing header may cost too much especially in ingress data packets to nodes with a high number of hops. For instance, a packet that is directed to a node in 20 hops consumes hundreds bytes in the source routing header, but the IP payload may be, for example, only 10 bytes. Some mechanisms have been identified to deal with these types of cases. For example, Request For Comments (RFC) 8138 ("IPv6 over Low-Power Wireless Personal Area Network (6LoWPAN) Routing Header") introduces the possibility of RPL data packet compression. But for a multiple packet case, the compressed IP headers still cost too much because the IP headers are always duplicated.

As a second example of such problems, data aggregation commonly would be leveraged to deal with the problem described above because in a traditional network fewer frames always means better performance – e.g., less contention, less header factorization, etc. However, in a LLN fewer frames may not in fact mean better performance because a larger frame has a higher chance of being dropped, resulting in the subsequent loss of all of the packets.

To address these types of challenges, techniques are presented herein that support the aggregation of data packets in a LLN without incurring a decrease in performance. Aspects of the techniques presented herein may be explicated with reference to Figure 2, below.

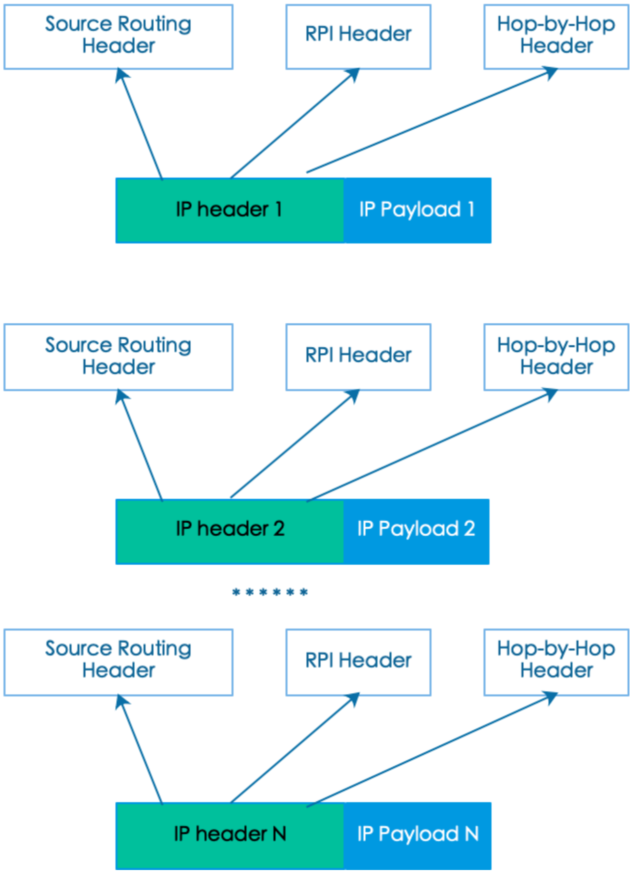

Figure 2: Multiple Packet Transmission

As depicted in Figure 2, above, when a root node sends multiple packets to a hop-1 node, the root node ends up transmitting numerous times with multiple IP headers and payloads.

Aspects of the techniques presented herein address such an excess by supporting the aggregation of IP packets with the same destination into one larger frame. Multiple packets are aggregated, thus saving duplicate IP headers. The root node then transmits just one large frame with a shorter total length, as illustrated in Figure 3, below.

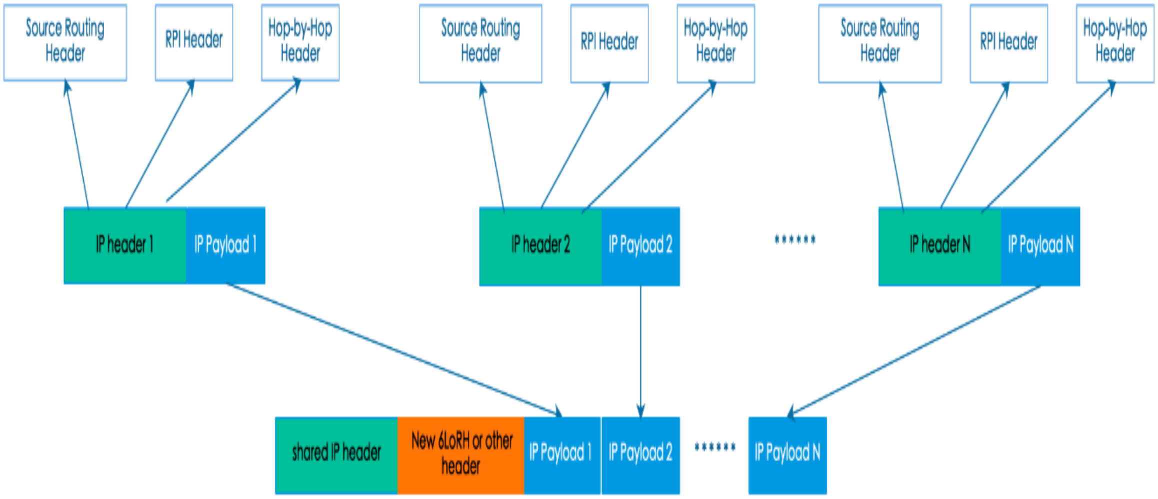

Figure 3: Aggregation of Packets

As illustrated in Figure 3, above, a new sub IP header is injected to facilitate data aggregation. One possible example of such a header could be a new 6LoWPAN Routing Header (6LoRH) as described in RFC 8138.

However, as noted previously, in a LLN, fewer frames does not necessarily always translate into improved performance because a larger frame has a higher chance of being dropped resulting in the subsequent loss of all of the packets. Accordingly, aspects of the techniques presented herein leverage the 6Lo fragments that are possible off of the aggregation to avoid the larger frame drop case, as shown in Figure 4, below.

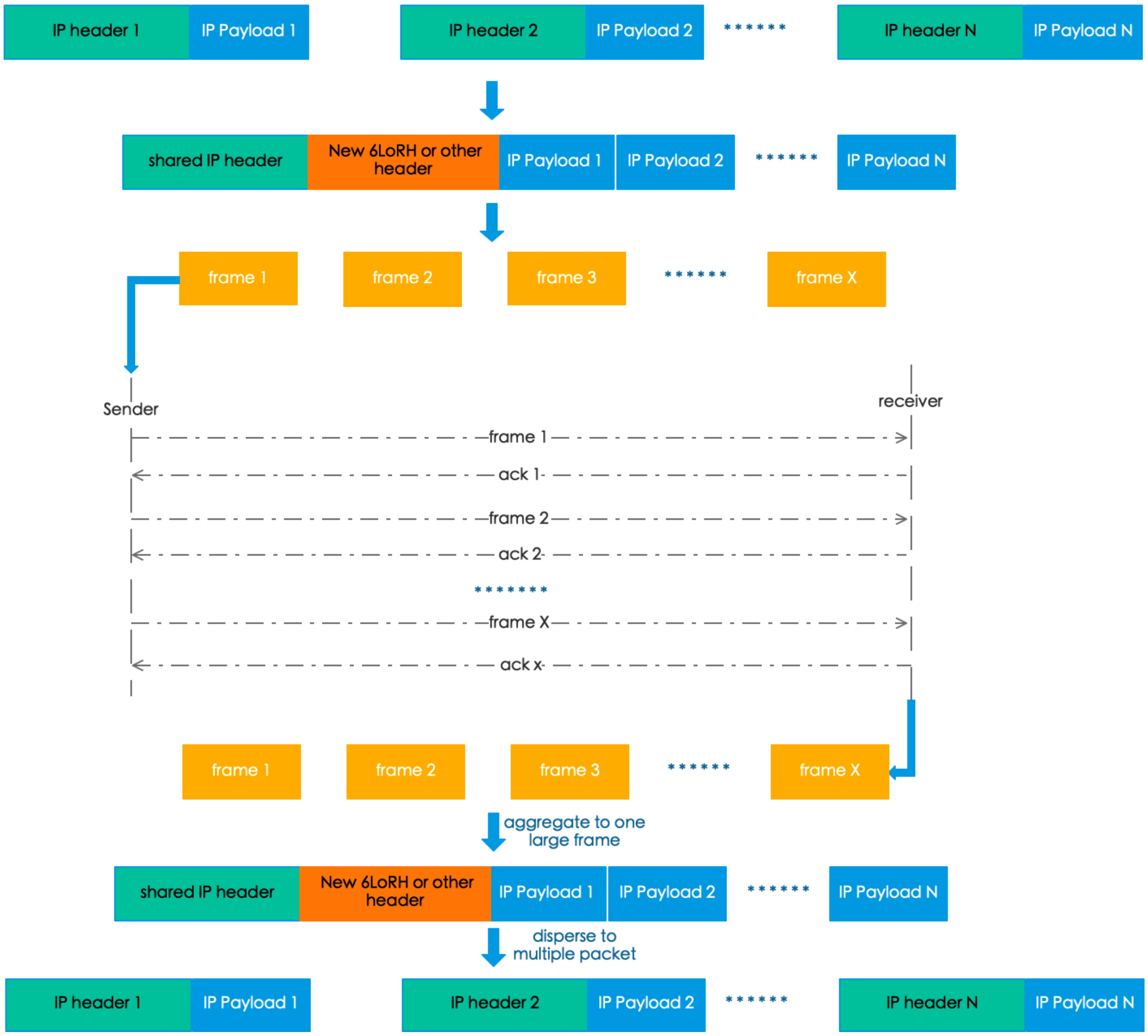

Figure 4: *Aggregation and Disassembly*

Extending the model that was depicted in Figure 4, above, aspects of the techniques presented herein enhance the MAC layer so that frames are grouped with just a single acknowledgement for all of the frames. One possible variation may incorporate a pure IP layer using 6LoRH in which case each frame is acknowledged but the receiver still expects that the sender will send X frames so they can refrain from contending.

Under aspects of the techniques presented herein, an introduction frame is sent containing the common header piece action as a Request To Send (RTS) for a block of X frames, followed by receipt of an acknowledgement that acts as a Clear To Send (CTS) for the X frames, and then the sequential sending of the X frames (with a 6LoRH indicating the frame number block and an acknowledgement request in the final frame). The X frames are separated by one flag but encompass a single transmission operation, where the sender is not waiting for an acknowledgement between the sending of each of the X frames. Finally, the sender receives an overall acknowledgement indicating which of the X frames were received. Then the receiver would prepend the common header or forward the burst to the next hop (again) using aspects of the techniques presented herein.

Figure 5, below, depicts elements of an illustrative example in accordance with aspects of the techniques presented herein, whereby multiple packets are sent from a root node (e.g., a source) to a hop 1 node (e.g., an intermediate) and then to a hop 2 node (e.g., a destination).

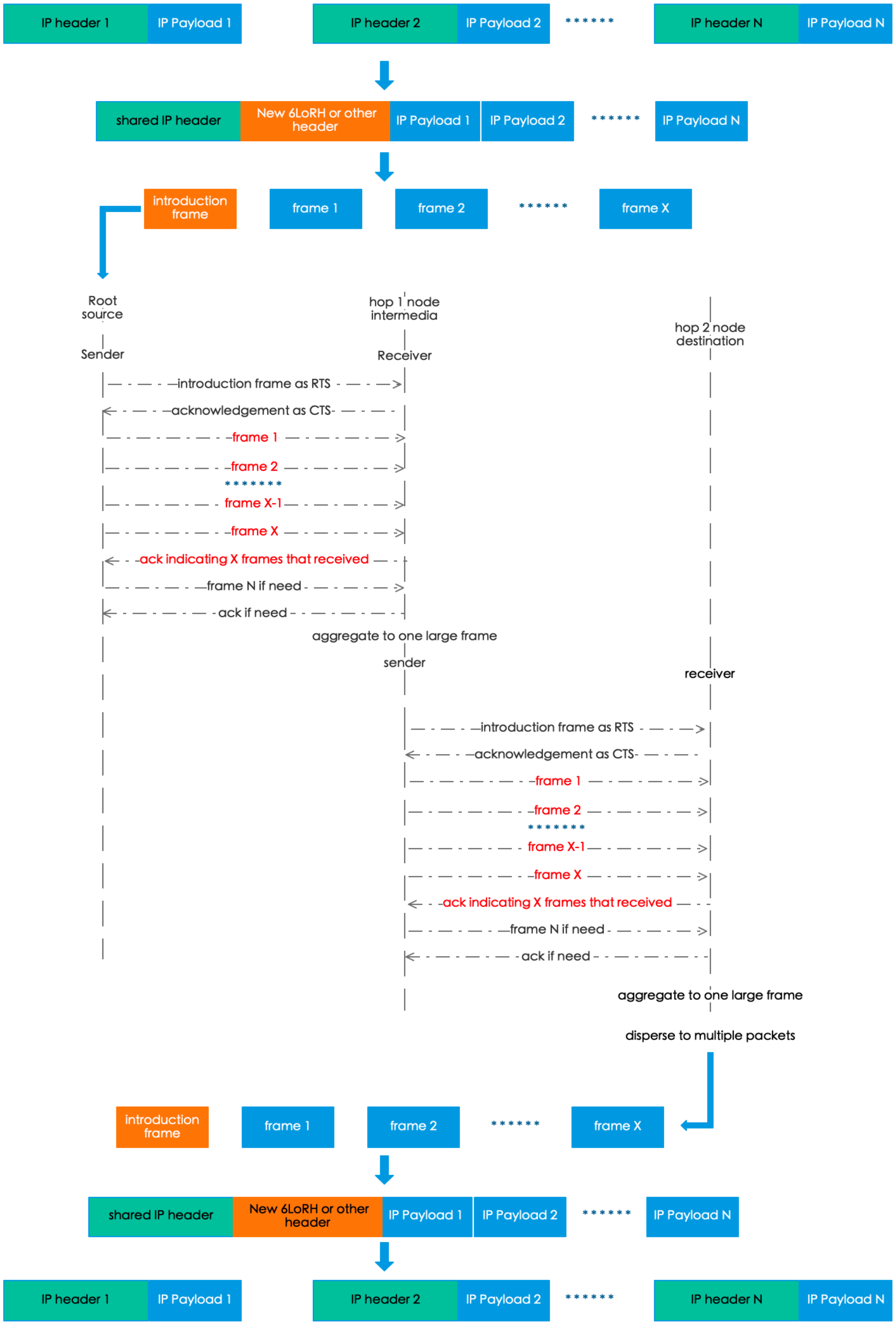

Figure 5: Illustrative Multi-Hop Example

RFC 8138 (6LoRH) does not provide for fragmenting, but RFC 4944 does provide for fragmenting. In one instance, techniques herein could transport RFC 4944 fragments in RFC 4944. Further, 6Lo does not provide for aggregation.

As depicted in Figure 5, above, and as described previously, aspects of the techniques presented herein support the introduction of a 6LoRH that supports a virtual serial transmission that both aggregates and fragments packets to form an ordered virtual bit stream (a virtual serial link). At the first aggregating point, packets from multiple sources are concatenated into a serial bit stream. That bit stream is truncated in packets of equal size to optimize the scheduling all the way to destination (e.g. typically up to the root). Each truncation is transported in a 6LoRH packet that is enough to transport the piece to the destination, where the bit stream is recomposed as if it was out of a PHY link and re-split into individual packets.

In summary, techniques have been presented that support a new way of aggregating data packets in a LLN without incurring a performance decrease. Aspects of the techniques presented herein leverage fragmenting of the aggregated data packets (to avoid instances of a larger frame being dropped) and enhance the MAC layer (so that frames are grouped with just a single acknowledgement for all of the frames).