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Analyzing 6LoWPAN/ZigBeeIP networks with the Perytons™ Protocol Analyzer

May, 2012

Background

While IP protocols are widely spread over broadband wireline and wireless communication means, transferring IP data over lower bit rate protocols has been always a challenge. The long headers of the IP layer and the layers on top of it made the use of IP over narrow band protocols such as IEEE 802.15.4, mostly inefficient.

Yet using IP instead of proprietary or application protocols designed specifically for low bit rates (e.g. ZigBee) has major advantages such as interoperability with other devices, possibility to use tools, applications and software stacks, use of standard Internet browsers, etc.

First introduced in 2007, the 6LoWPAN protocol is designed as an optimization method for efficient transmission of IP layers on top of IEEE 802.15.4 networks. The 6LoWPAN documents define ways to compress various IP layer headers into very small packets by removing redundant information, and optimizing the number of bits allocated to fields with common values. 6LoWPAN provides some additional adaptation layer services such as fragmentation to handle long IP packets sent on top of relatively short 802.15.4 packets, mesh routing etc.

A typical structure of IP over IEEE 802.15.4 with 6LoWPAN is sown in Figure 1.

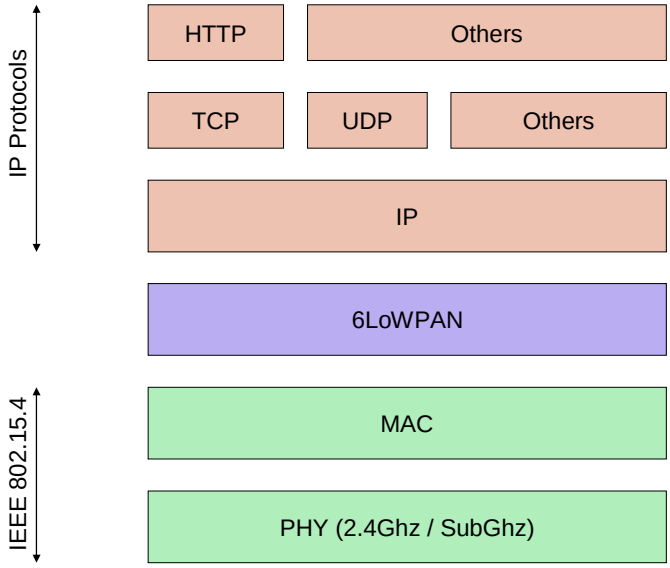

Figure 1 - IP Layers

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When analyzing and debugging an IP network/s running on top of IEEE 802.15.4, there are several challenges expected:

- Data capture

  Typical capture devices for IP network are suitable for typical PHYs such as Ethernet or WiFi. Capturing 802.15.4 traffic requires suitable wireless capture devices for 2.4 GHz and/or for Sub 1 GHz frequency bands

- IEEE 802.15.4 decoding and analysis

  Some of the network features (e.g. low layer acknowledgments, encryption, etc.) are accomplished at the MAC layer and should be decoded

- Defragmentation of 6LoWPAN packets

  Each IP packet may spread over multiple 802.15.4 packets. In order to analyze the IP traffic, the fragmented packets must be reassembled

- Handling 6LoWPAN MESH routing

  Mesh routing done by the 6LoWPAN layer should be analyzed and displayed in an easy to understand way

- Handling 6LoWPAN compression

  For each IP protocol the 6LoWPAN defines a dedicated compression scheme. Consequently before analyzing the IP layers, the IP packets should be decompressed into their original format

- Analyzing the IP packets

  The IP packets content should be displayed to the user in an easy to understand way

- Handing TCP segmentation and acknowledgments

  Long payload packets are split by the TCP layer to segments (i.e. fragments). 'Sliding window' acknowledgments are used for efficient retransmission. Due to memory limitations of typical 802.15.4 devices, the segments are limited in length.
  Therefore, before upper layers analysis can be performed, a 'de-segmentation' process of the TCP layer (per each source and destination address/ports combination) needs to be performed

- Handing upper layers protocols

  There are many protocols that can run on top of TCP/UDP layers. The common ones being HTTP (browsing), FTP (file transfer) and various e-mail protocols (e.g. POP3). Presenting each of the protocols to the user in the best way can be a challenge as well

Perytons™ solution

While there might be different analysis needs for Mesh wireless networks vs. IP based protocols, and separate tools available for each in the market; a single tool where both dimensions are easily presented can make an important difference to the process of the R&D, QA and integration groups.

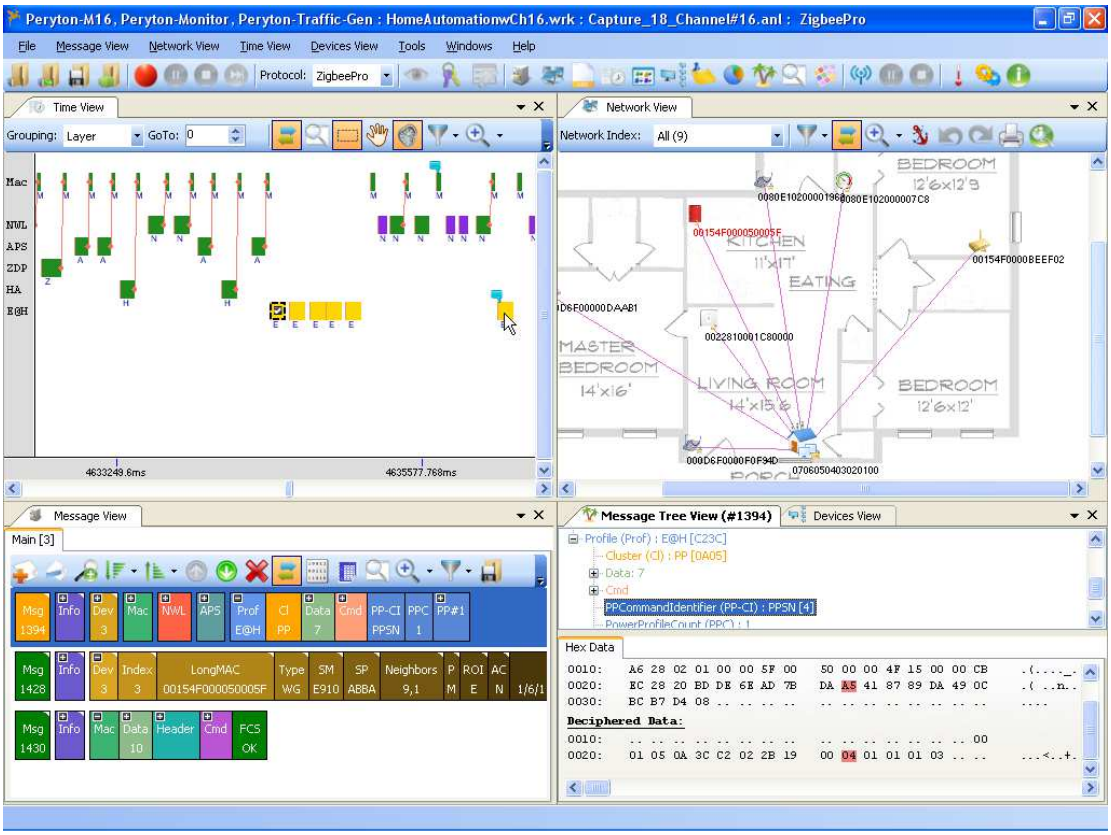


Figure 2 – Perytons™ Protocol Analyzer main-screen showing the standard views when analyzing a 802.15.4/ZigBee based Mesh network

The Perytons™ Protocol Analyzer is a powerful analysis tool that integrates special viewing options and features specially suitable for IP based protocols (like 6LoWPAN), combined into a single environment that includes the Mesh Network analysis and allows the user to easily and quickly identify potential issues and correlate between these sometimes separated 'worlds'.
Sophisticated features related specifically to IP content (like browser-like HTTP presentation, etc.) can save a lot of precious development and debugging time:

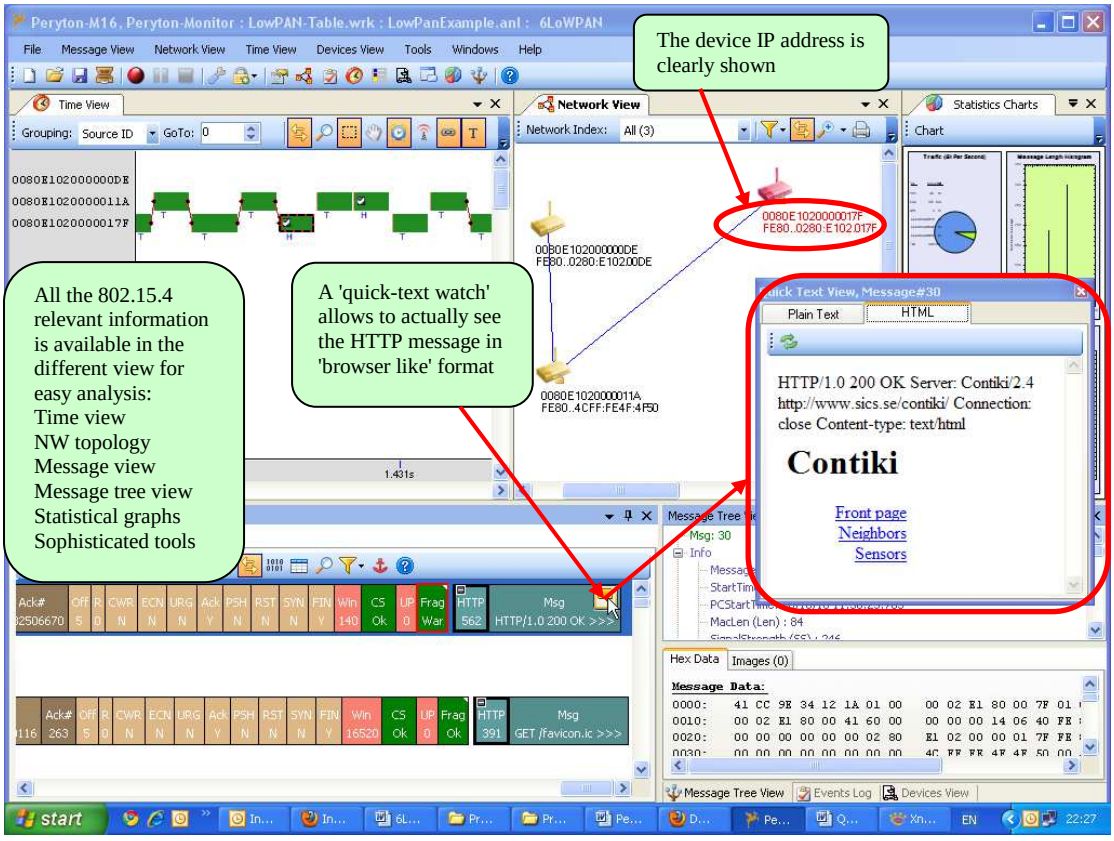
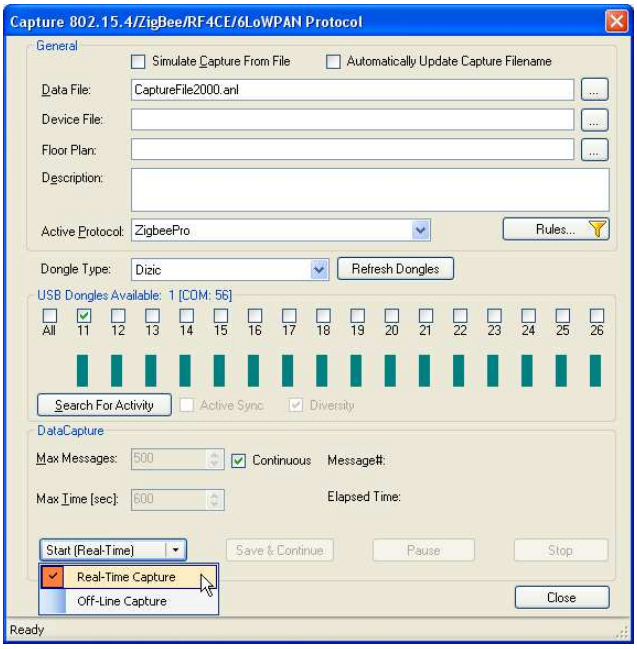


Figure 3 – Perytons™ Protocol Analyzer main-screen showing IP over 6LoWPAN network

- Data capture



The Perytons™ Protocol Analyzer uses off the shelf IEEE 802.15.4 USB dongles as front-ends to capture data in both the 2.4GHz and the Sub1 GHz frequency bands. They include a diversity feature allows improving in-door reception performance by using two receivers per channel, enabling the analyzer to capture a more complete wireless picture. In addition, multi-channel capture allows to monitor networks that use frequency hopping 802.15.4 (e,g. wireless HART), automatic channel selection algorithms and multiple networks coexisting in the same proximity

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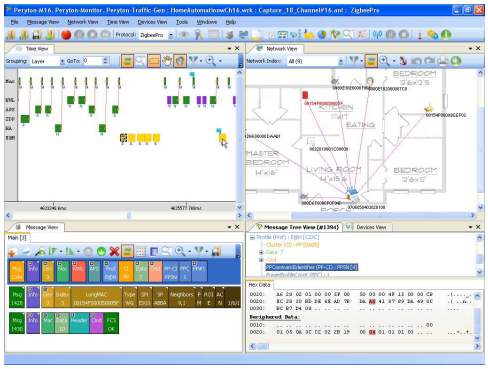
- IEEE 802.15.4 decoding and analysis

  The Perytons™ Protocol Analyzer decodes the IEEE 802.15.4 MAC traffic, displays the data in a variety of views (vs. time, network topology, various displays of packet fields, statistical charts, etc.) and includes an enhanced sophisticated toolbox for further analysis

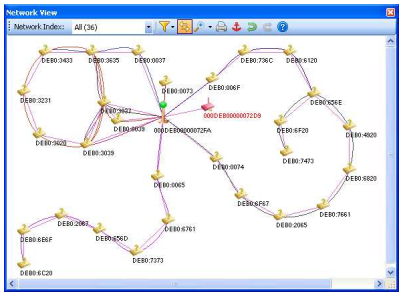


- Defragmentation of 6LoWPAN packets

  Each IP packet may spread over multiple 802.15.4 packets and in order to analyze the IP traffic, the fragmented packets must be rearranged.
  The following example shows a single IP packet divided into two fragments. The first one (message 23) holds the 6LoPAN header with some payload data and the second one holds the remaining IP data. When set to analyze 6LoWPAN protocols, the Perytons™ Protocol Analyzer combines the fragments and associates the full 6LoWPAN payload (IP packet) to message 25

- Handling 6LoWPAN MESH routing

  Within the integrated Network View, the auto-discovered network topology is displayed in an easy to understand way

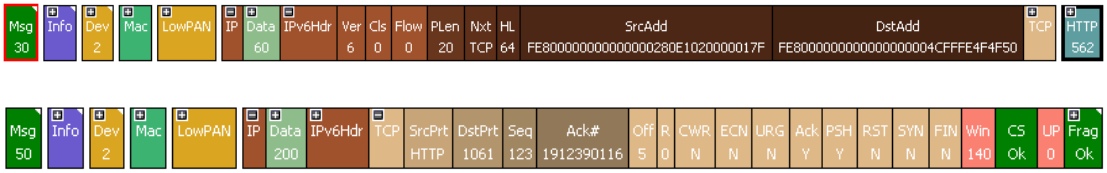


- Handling 6LoWPAN compression

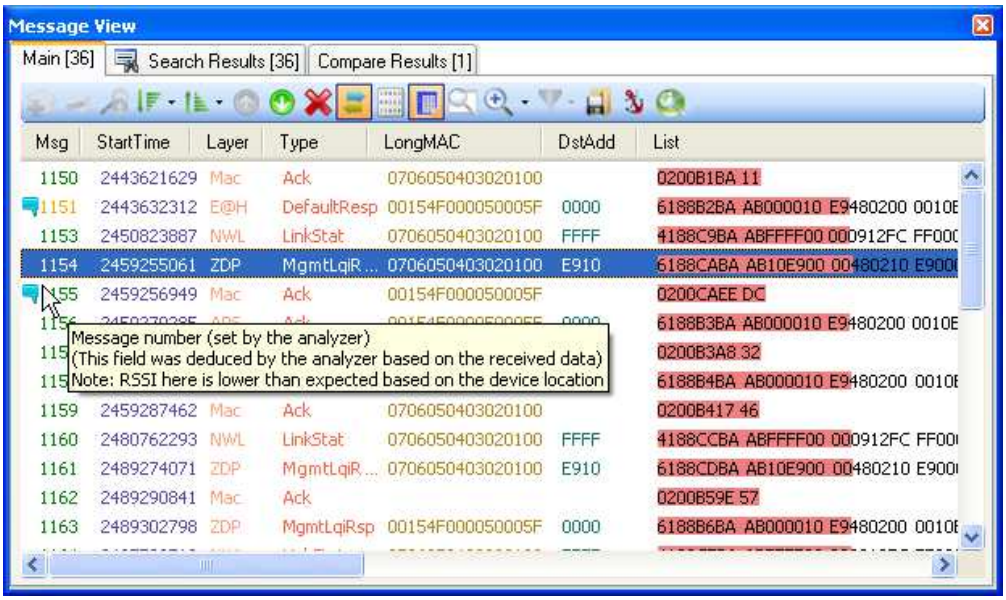
  For each IP protocol the 6LoWPAN defines a dedicated compression scheme. Before analyzing the IP layers, the Perytons™ Protocol Analyzer decompresses the IP packets into their original format

- Analyzing the IP packets

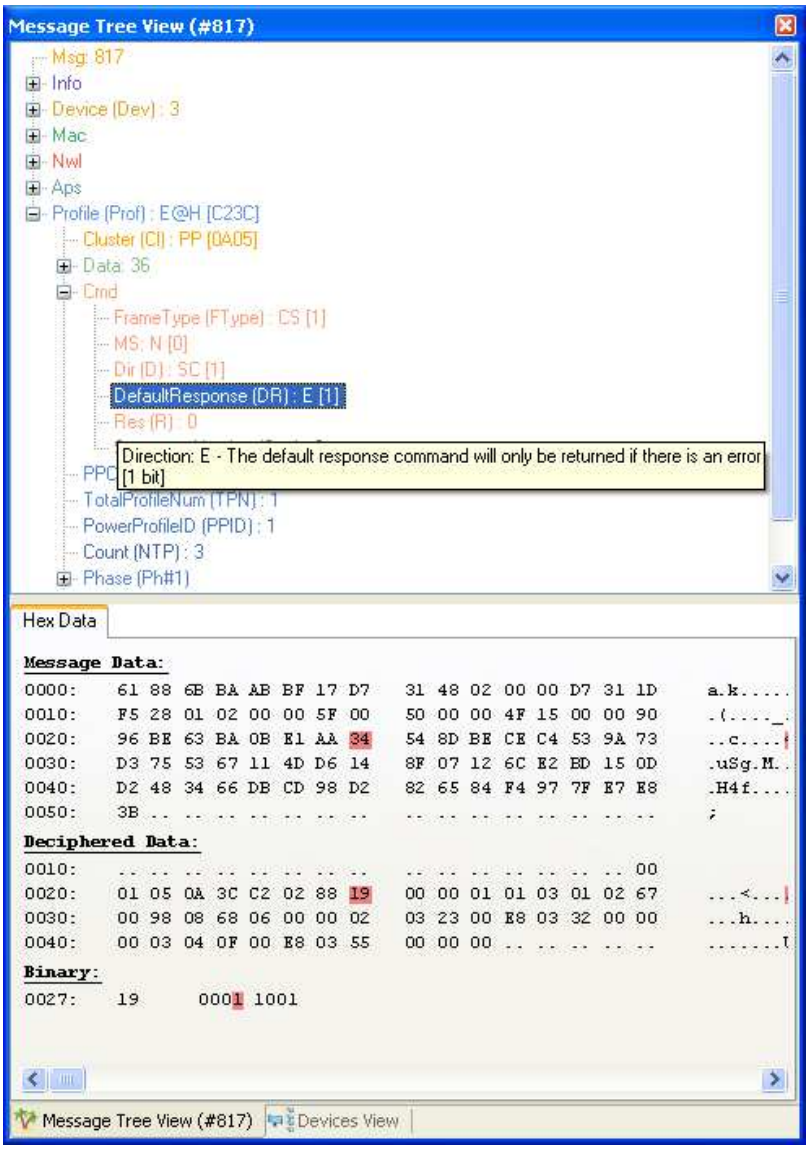
  With the Perytons™ Protocol Analyzer the user can chose the way he prefers to display the IP packets:



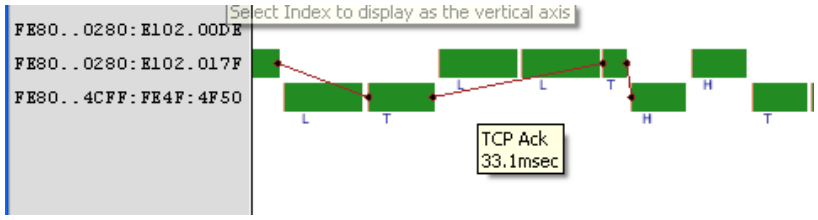
For users who prefer a textual view over graphical one, the message content can be shown in a table, where the user can choose which columns will be displayed or hidden, set their order, sort the messages by each column, etc. – but still keep the hints and other features included in the graphical display mode:

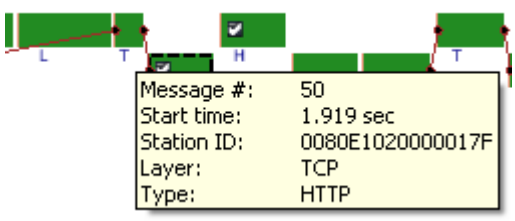


Message fields can be also explored in a colored coded Tree View (XML like) style showing each bit meaning and value and highlighting it in the message hexadecimal data:



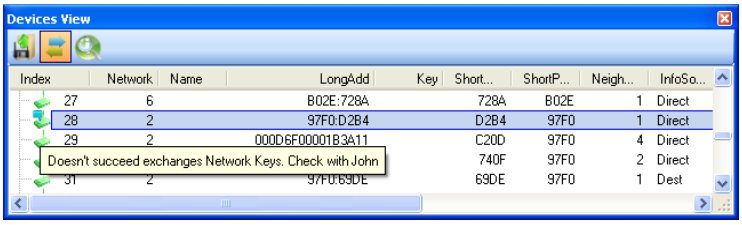
Transactions are shown over time and with easy to read and useful relevant information:





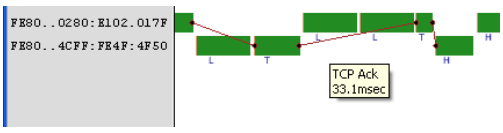
And devices are shown in a graphical auto-discovered network topology including relevant information for each device (e.g. IP address, user note) and allowing using sophisticated tools for advanced analysis (show all messages from/to a specific device, show all messages that passed over a specific communication path, etc.):

Alternatively the devices with all relevant information can be explored in a table format and exported to file for further analysis:

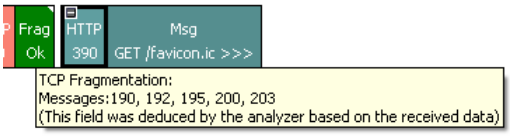


- Handing TCP segmentation and acknowledgments

  Long payload packets are split by the TCP layer to segments (i.e. fragments). 'Sliding window' acknowledgments are used for efficient retransmission:



  Due to memory limitations of typical IEEE 802.15.4 devices, the segments are limited in length.
  The Perytons™ Protocol Analyzer performs a 'de-segmentation' process before upper layers analysis of the TCP layer takes place (this process is done per each source and destination address/ports combination):

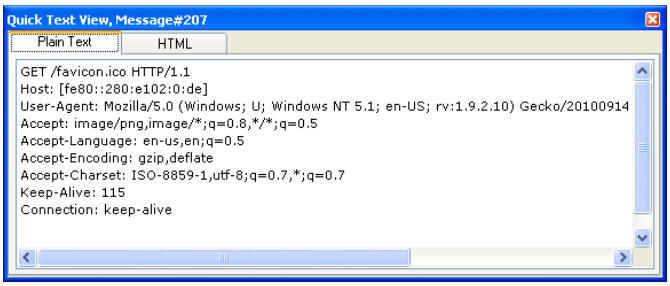


- Handing upper layers protocols

  There are many protocols running on top of TCP/UDP layers. The common ones being HTTP (browsing), FTP (file transfer) and various e-mail protocols (e.g. POP3).

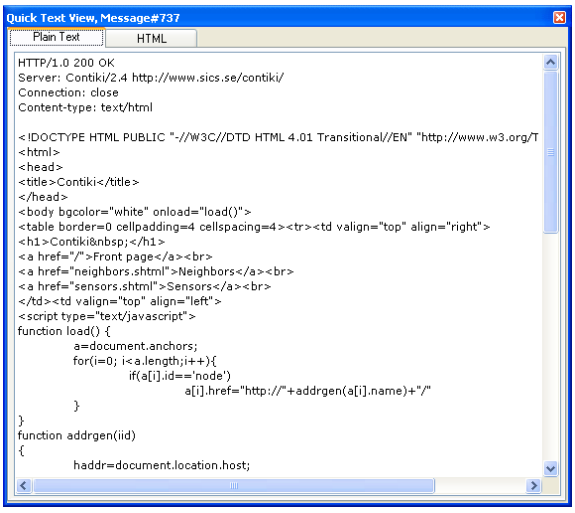
  The following example shows how an HTTP layer is displayed in the Perytons™ Protocol Analyzer environment.

  The request (from browser to server) is shown in a text window:

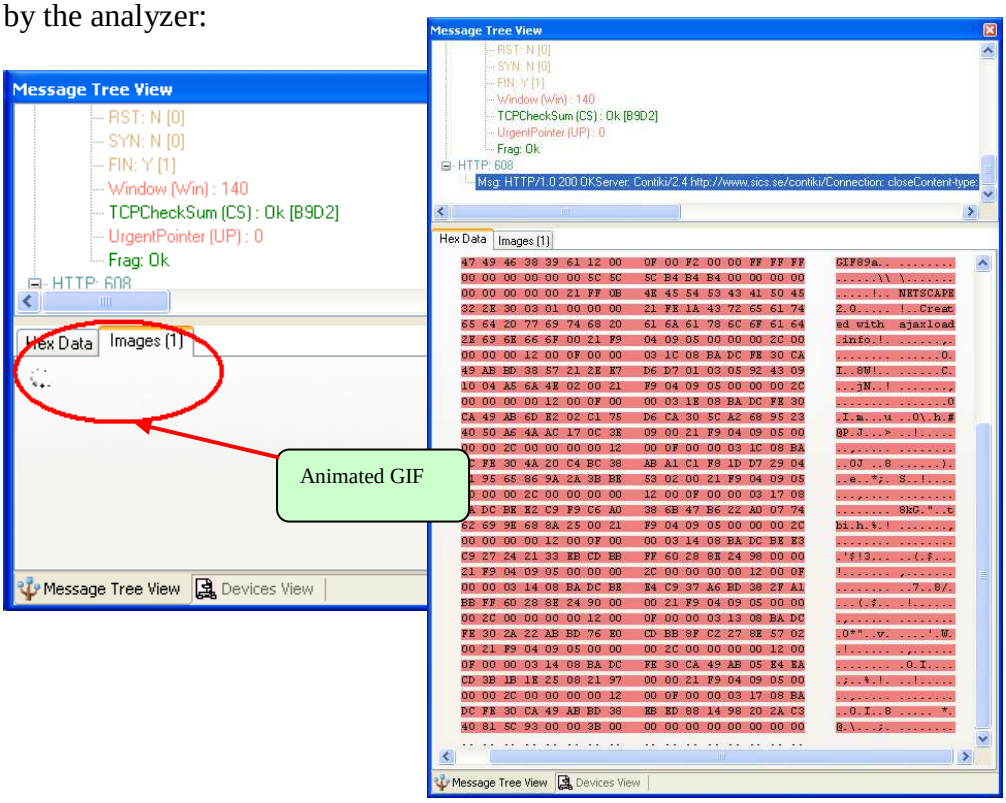


  The response, is shown in an integrated browser window:

  or in a 'plain text' window:

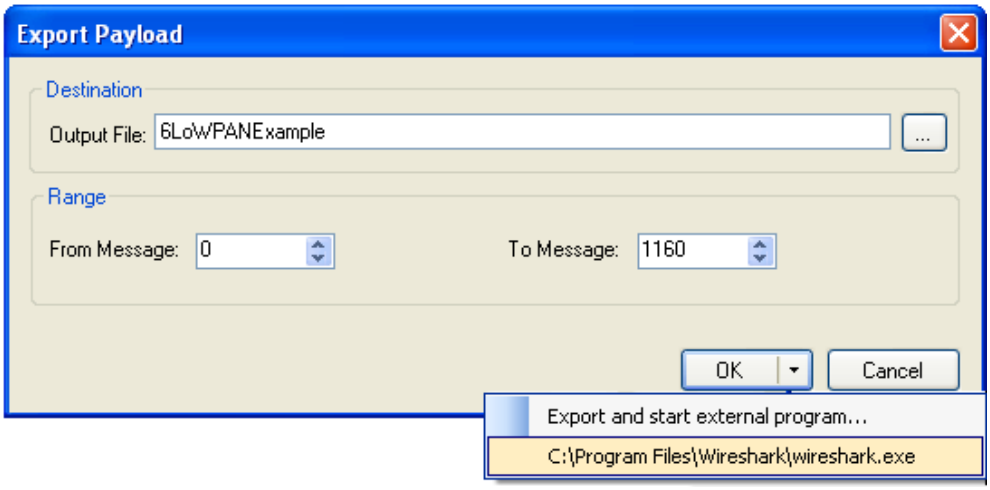


If the HTTP message contains an image, the image is decoded and displayed by the analyzer:



All analyzed layers gain the Perytons™ Protocol Analyzer intuitive UI and enhanced toolbox including search tool, message compare, Open Source Rules, statistics charts and more.

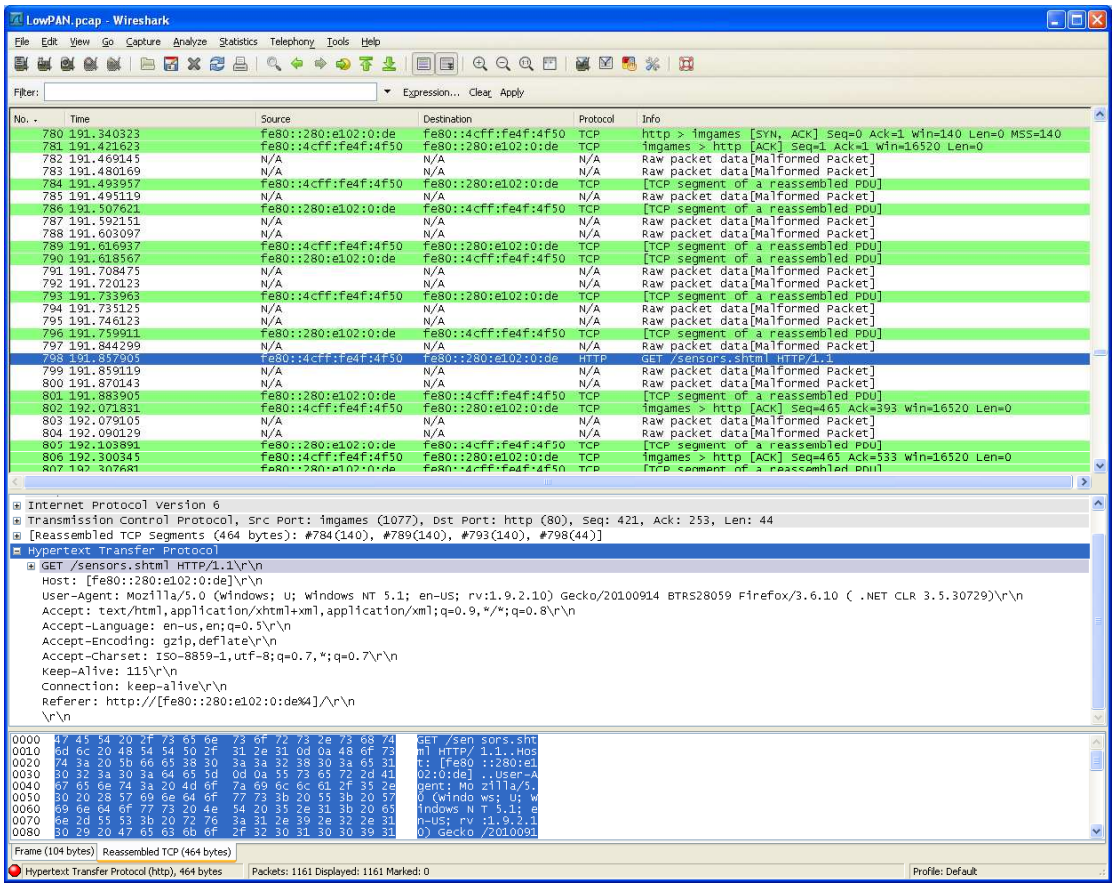
In addition to the built in Perytons™ Protocol Analyzer features, the IP data can be exported to other (external) tools for further analysis:



Other tools available in the market

The main tool used today for analyzing traditional IP networks is Wireshark. This is an open source, textual protocol analyzer supporting many IP and non IP protocols.

When buying dedicated capture hardware, Wireshark can capture and analyze 6LoWPAN traffic. The same capture file shown in the previous Perytons™ Protocol Analyzer screenshots, is shown in the following Wireshark screenshots:.



The Wireshark analyzer shows the decoded fields in textual mode only. Table columns maybe selected and their order can be changed. Data can be filtered by field values.

While Wireshark supports many protocols the Perytons™ Protocol Analyzer doesn't (e.g. X.25); most of these protocols are not relevant for the typical 6LoWPAN user. The relevant 6LoWPAN layers are well supported by the Perytons™ Protocol Analyzer including all the additional features presented in the previous section and are absent in the Wireshark tool.

Being analysis tools the focus of Perytons™, the company constantly adds new protocol layers and 6LoWPAN flavors into the analyzer in a timely manner and taking into consideration the market needs.

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Summary

The Perytons™ Protocol Analyzer is an enhanced professional wireless protocol analysis tool. With the 6LoPWAN and IP layers integrated support, the Perytons™ Protocol Analyzers address the need for an easy to use and yet professional tool essential to help understanding of the 6LoWPAN and IP over sensor networks.
The combination of a tool capable of both handling IEEE 802.15.4 based networks as well as 6LoWPAN and IP layers analysis is crucial for helping in identifying and quickly resolving problems. Most of the Perytons™ Protocol Analyzer features are unique and can not be found in other analysis tools available in the market.