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TinyIPFIX for Efficient Data Transmission in Wireless Sensor Networks

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Agenda

- Motivation
- Constraints

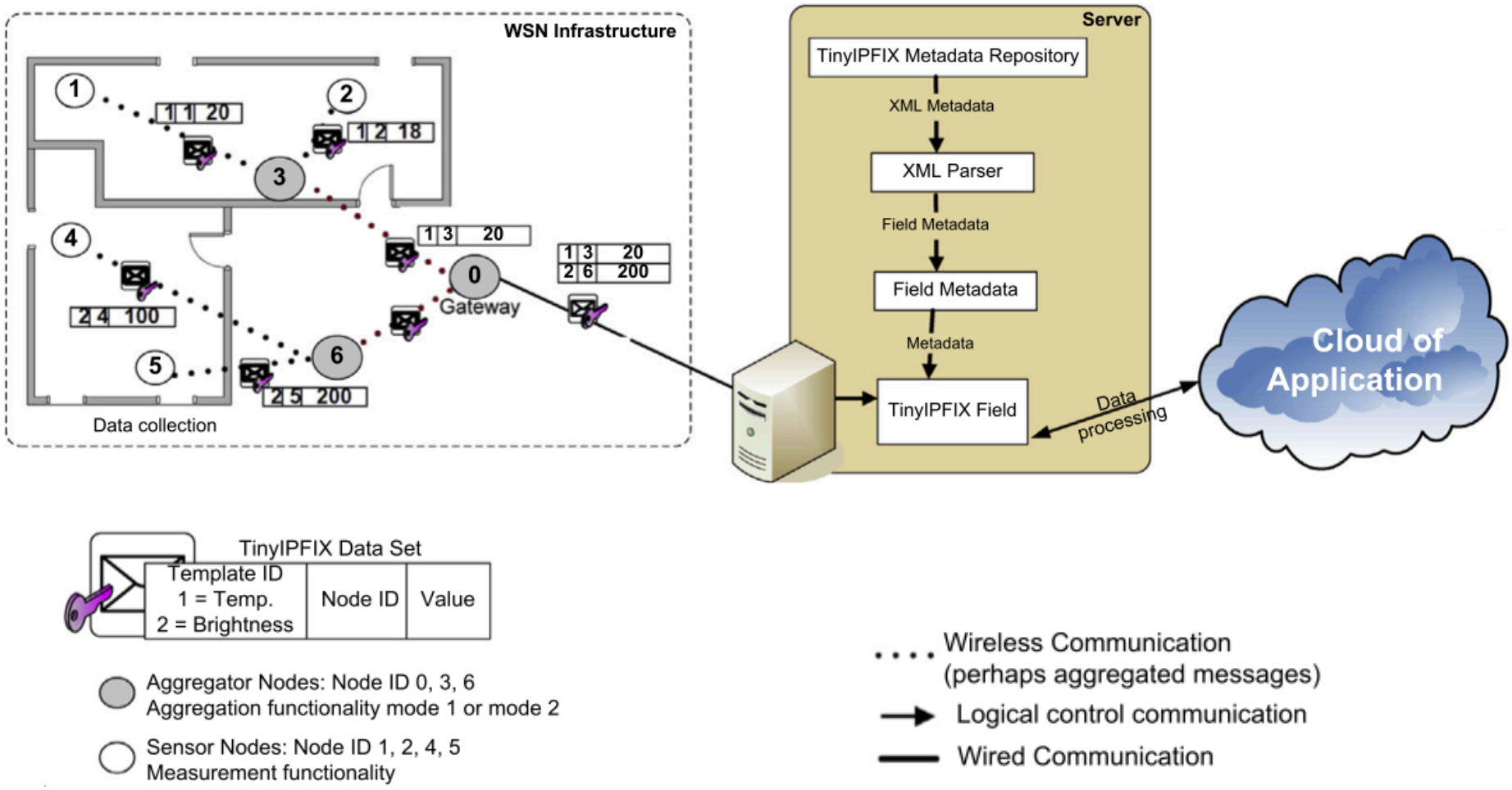
- Efficient Data Transmission
  - IPFIX → TinyIPFIX for Wireless Sensor Networks
  - TinyIPFIX Pre-header
  - Evaluation

- Summary

Motivation

- Smart meters that form a constrained Wireless Sensor Network (WSN) need an application protocol that allows the efficient transmission of metering data.
  - The meters are usually equipped with low-cost and low-power hardware.
  - Constraints
- Smart meters
  - Do not have a steady network connection
  - Are only part of the WSN as needed when there is data to transmit.
- Push protocol like TinyIPFIX is suitable for reporting metering data in WSNs
  - Data is transmitted from the meters to one or more collectors only.

Architecture



Constraints

- Memory

Name	data size (e.g., RAM)	code size (e.g., Flash)
Class 0, C0	<< 10 KiB	<< 100 KiB
Class 1, C1	~ 10 KiB	~ 100 KiB
Class 2, C2	~ 50 KiB	~ 250 KiB

Table 1: Classes of Constrained Devices (KiB = 1024 bytes)

- Energy: Usually battery powered with AA battery pack

- Packet size constraints
  - WSNs use IEEE 802.15.4 [RFC4944]
  - Maximum frame size of 127 octets → 201 octets for data
  - IPv6 defines minimum MTU of 1280 octets → Fragmentation

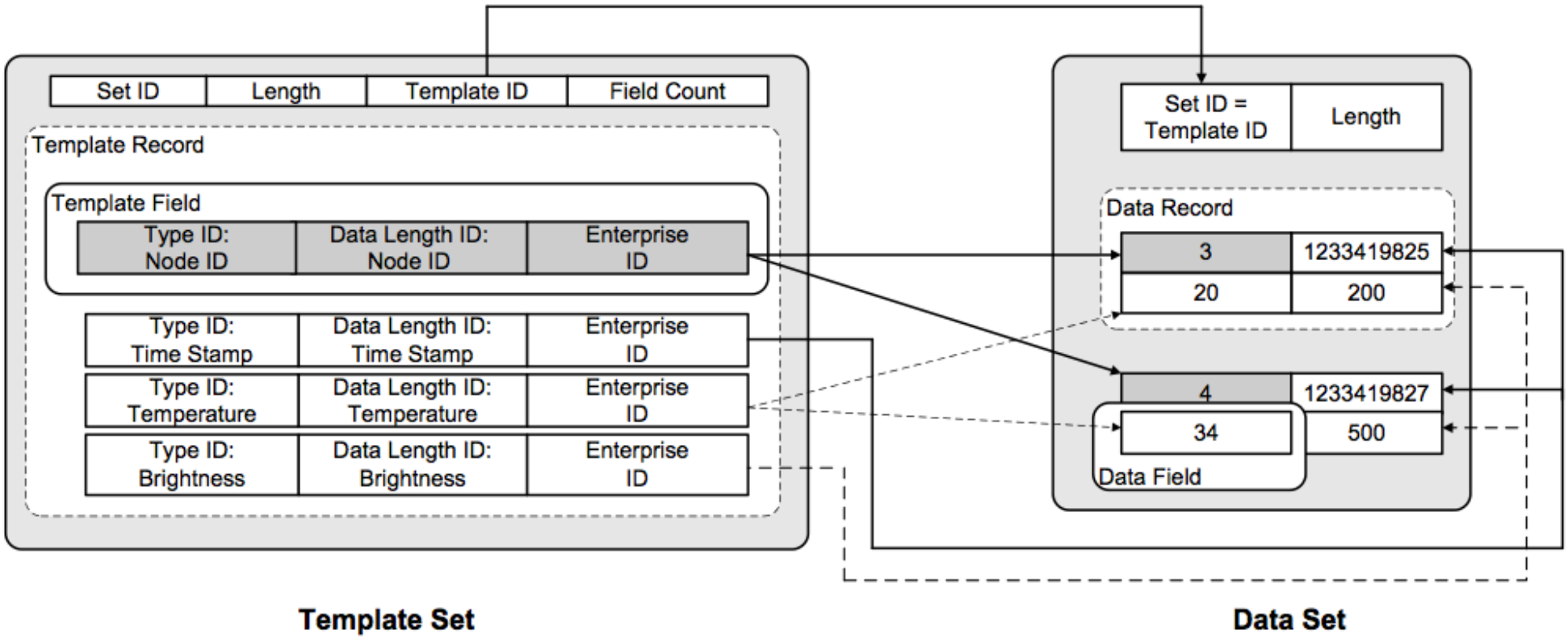
Efficient Data Transmission

- Current Status:
  - Periodical transmissions
  - Each transmission includes meta information and measured data.
  - For each sensor node it is assumed that the meta information stays the same. → Redundancy

- Solution: IP Flow Information Export (IPFIX) protocol
  - Developed for flow observation in networks
  - IETF Standard
  - PUSH protocol with Template-based design

    → Separation between meta information and data

IPFIX Concept

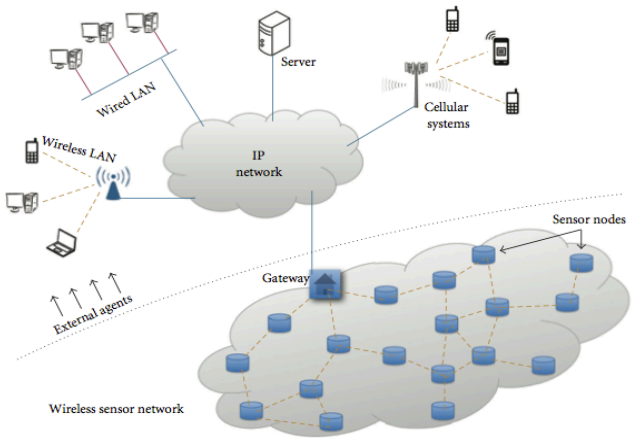


IPFIX → TinyIPFIX For WSNs

- Drawbacks of IPFIX
  - IPFIX itself is not pre-paired for sensor measurements!
  - Big overhead due to additional headers (IPFIX Message and Set Header).
  - Limited message size 102 bytes individual payload due to RF Transceiver CC2420.

- Required modification For WSN usage:
  - Register different IDs by IANA: Type IDs, Enterprise IDs, IPFIX templates
  - Reduction of overhead by pre-header

- Result:
  - First announce Template
  - Continue only with Data Records
  - Saving bits!



IANA Issues

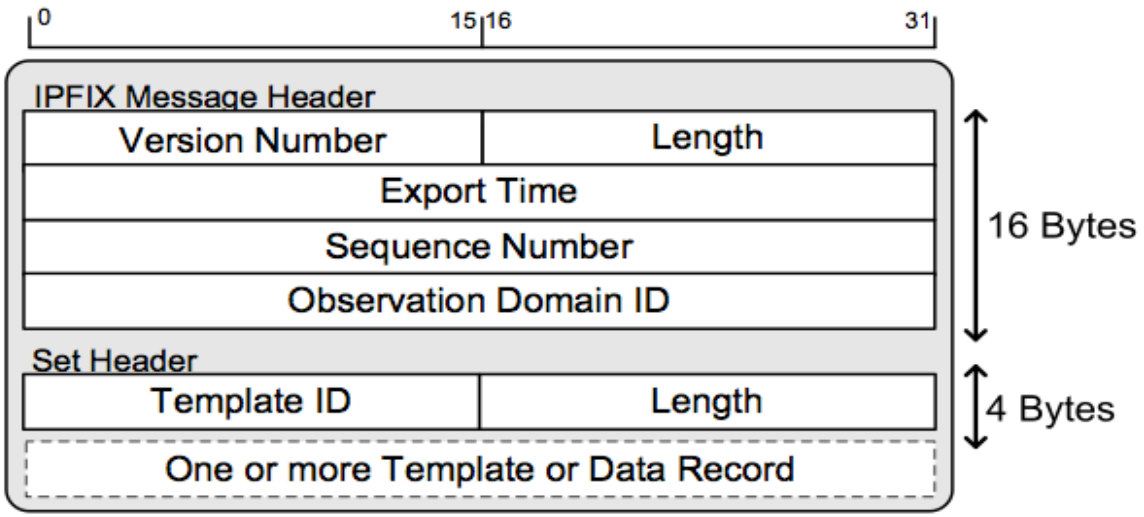
- Standardized Type ID and Enterprise ID
  - Enterprise ID is independent of hardware platform and platform vendor
  - Enterprise ID depends on sensor and vendor of technical unit

Hardware platform	Platform vendor	Sensor	Vendor technical unit	Enterprise ID	Type ID
TelosB	Advantic Sys.	Temperature	Sensiron SHT11	3841	33025
TelosB	Advantic Sys.	Humidity	Sensiron SHT11	3841	33026
TelosB	Advantic Sys.	Light	Hamamatsu S1087	3845	33025
IRIS	Crossbow Inc.	Temperature	Panasonic ERT-J1VR103J	3843	32771
IRIS	Crossbow Inc.	Light	TAOS TSL2550	3846	33282

  - Include semantics and type length → interoperability

IPFIX Headers

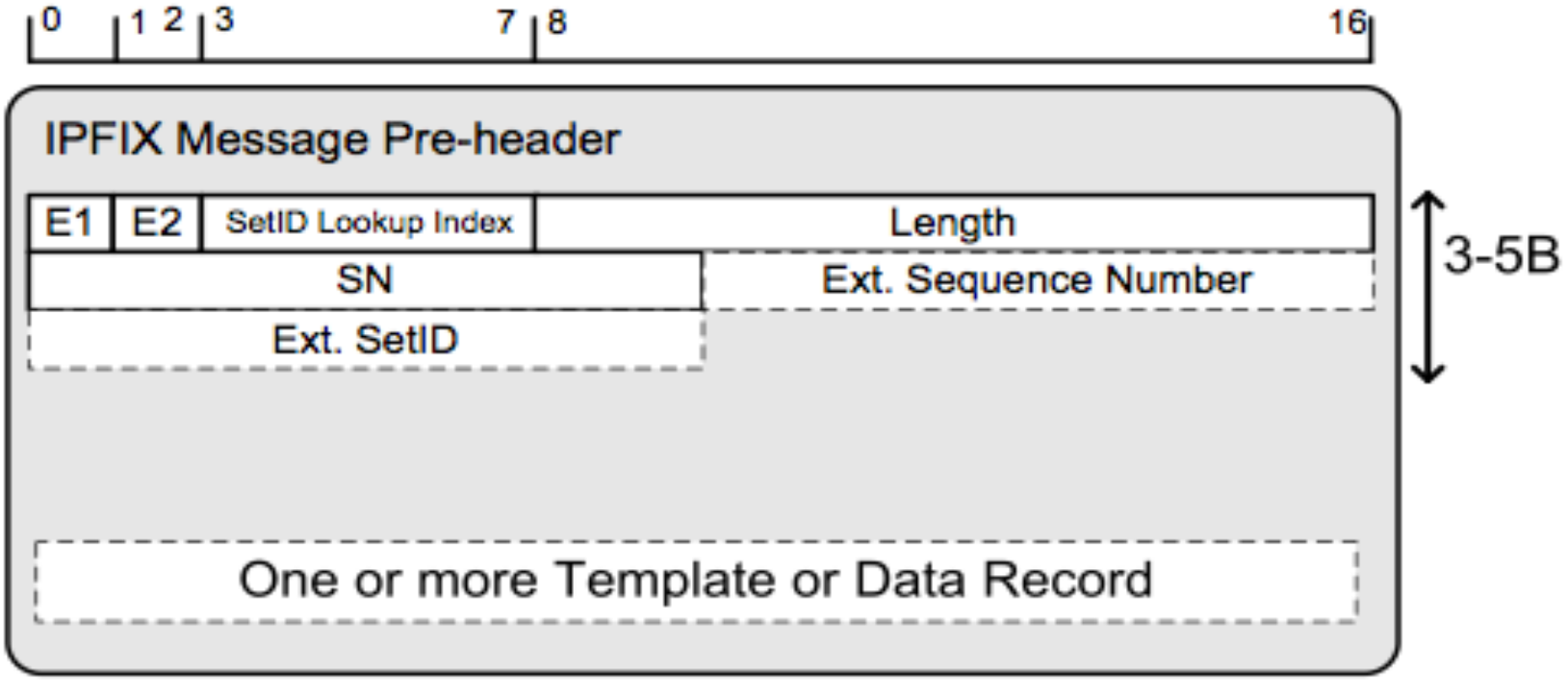
- General size: 20 Bytes



- Size reduction possible, because ...
  - ... data can be recalculated from other sources.
    - Observation Domain by underlying network protocol
    - Export Time included as field in Template
  - ... number of supported IPFIX versions can be limited.
  - ... a pre-header is introduced specifying the length of each field size.

TinyIPFIX - Pre-header (1)

- Specification of what is expected to come



TinyIPFIX - Pre-header (2)

- Bit E1 controls the presence of the extended SetID field
- Bit E2 specifies the length of the Sequence Number field
- E1 ≠ 0 and E2 ≠ 0 → optional fields are required
  - E1 → controls presence of Ext. SetID
  - E2 → length of field Ext. Sequence Number

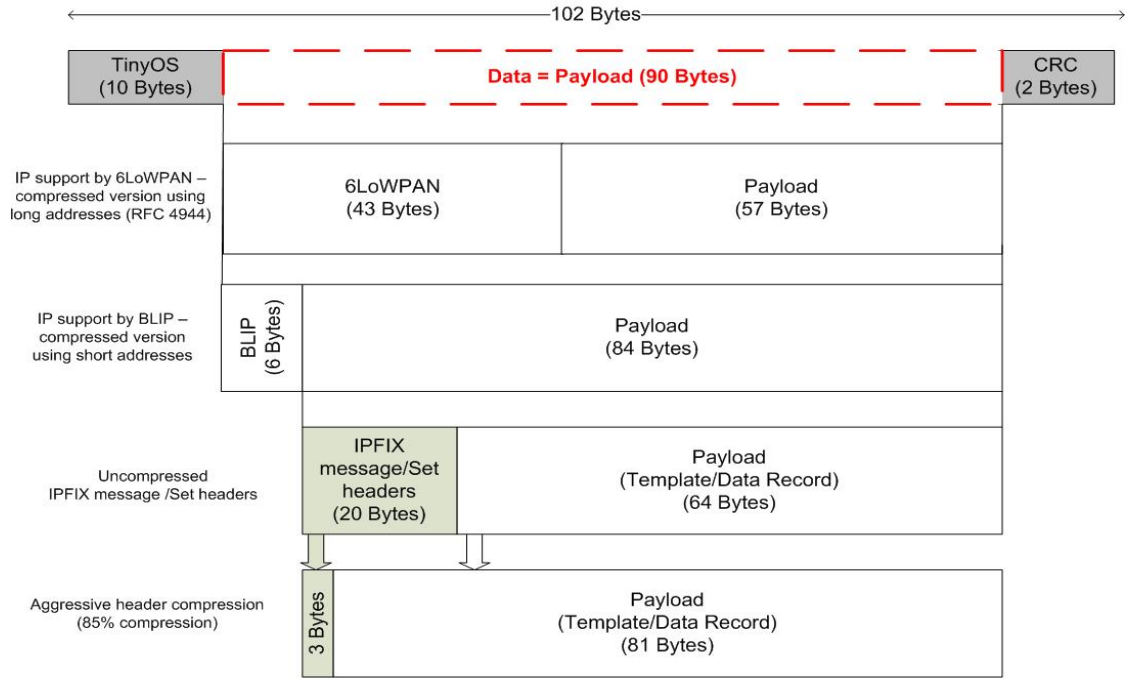
- SetID Lookup field acts as a lookup field for the SetIDs and provides shortcuts to often used SetIDs.
  - SetID Lookup Index = 0 → proper SetID definition follows
  - SetID Lookup Index = 1 → SetID = 2 → message contains Template Set
  - SetID Lookup Index = {2..63} → reserved
  - SetID Lookup Index = {64..255} → message contains Data Set referencing Template

- Optional fields: Ext. SetID and Ext. Sequence Number

- Sequence Number (SN) =1 byte

MTU usage of TinyIPFIX in TinyOS

- TinyIPFIX currently implemented for TinyOS
- Runs on IRIS, TelosB, OPAL
- RF Transceiver CC2420 is IEEE 802.15.4 compliant and supports MTU =127 octets → MAC layer limitation to 102 octets



Evaluation

Memory usage of BLIP and TinyIPFIX [bytes].

Component	RAM	ROM	TinyIPFIX packet
Scaffold	46	2826	–
BLIP	4738	23,012	–
TinyIPFIX	57	2972	0
	261	3182	102
	2105	3012	1024
Total	4841–6889	29,020	0–1024

Average transmission times and energy consumption. TLV^{8} and TLV^{48} refer to one and 6 bytes for the length of the "Type" field.

Packet type	t_{send} (ms)	Payload (bytes)	Energy (μJ)
empty	10.48	0	699
TLV 2^8	10.93	14	730
TLV 2^{48}	11.55	34	778
IPFIX Data	11.69	30	779
IPFIX Template	12.3	48	820
TinyIPFIX Data	10.9	13	727
TinyIPFIX Template	11.71	31	780

TLV 2^8 = TLV with a length of 1 byte for the type field
TLV 2^{48} = with 6 bytes

Summary

- TinyIPFIX defines an efficient data format for transmitting sensor measurement data using low bandwidth.
- Little processing power is needed.
- Arbitrary aggregation techniques can be deployed.
- Interoperability can be ensured.
- Using IP on the network layer below IPFIX to integrate WSNs easily in existing home networks is possible

- New approach for data transmission in WSNs
- Successful deployment for over 7 years
  - IRIS, TelosB, OPAL

References

- C.Schmitt, T.Kothmayr, B.Ertl, W.Hu, L.Braun, G.Carle: TinyIPFIX: An Efficient Application Protocol For Data Exchange In Cyber Physical Systems, Journal Computer Communications, DOI: 0.1016/j.comcom.2014.05.012, June 2014

- T.Kothmayr, C.Schmitt, L.Braun, G.Carle: Gathering Sensor Data in Home Networks with IPFIX, European Conference on Wireless Sensor Networks (EWSN) - LNCS 5970, Coimbra, Portugal, February 2010

- http://www.csg.uzh.ch/research/SecureWSN.html

Thanks ...