TinTin: Tiny In-Network Transport for High Precision INdustrial Communication

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Outline of the presentation

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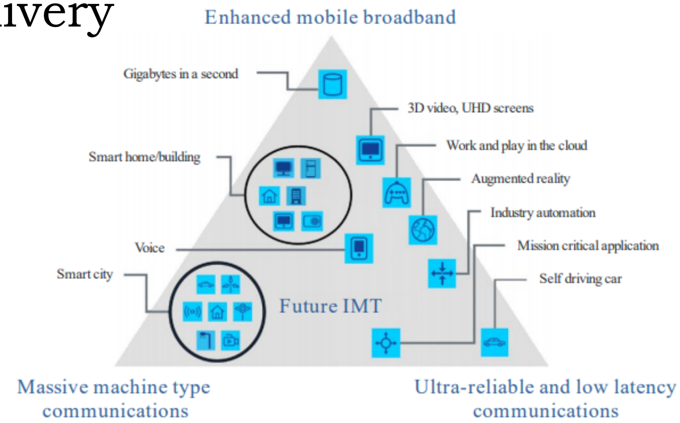
- Conclusions and Future Work

Introduction

Introduction

- Industry 4.0
  - Support for different types of connections (short lived, long lasting)
  - Support for high precision communication
  - More stringent requirements than real-time operations
- Critical requirements from the network
  - High reliability in machine-centric data delivery
  - Fine-grained customisation of traffic
  - Guarantees of data delivery
  - Lossless traffic flow between the endpoints
  - Digital Sovereignty and Preservation of Privacy
  - Digital Twins and Cyber Physical Systems



Source: ITU-T

Introduction (contd …)

- Recent innovations in network technologies!
  - New IP at Layer 3
  - Deterministic Networking (DetNet) at Layer 3
  - Time Sensitive Networking (TSN) at Layer 2
  - What is the major challenge?
    - Mechanisms for endpoints to leverage these new capabilities
- Need for a new transport protocol
  - that can utilize the new network services
  - satisfy the requirements of industrial applications
    - For example: meet the latency and timeliness guarantees

High Precision Communication

Characteristics

- Although less constrained than IoT, the communication in Industrial IoT is characterized with the following:
  - Time-critical
    - Every operation is executed in or at a specific time precisely without complex state management
  - Safety-critical and Reliable
    - The accuracy of each command received is utmost critical; the data cannot be lost or arrive incorrectly
  - Resource-constrained
    - It is extremely important to maintain a light-weight network stack on field-devices
  - Stateless and Session-free
    - Neither session based QoS is useful nor maintenance of long-lived sessions on endpoints

Motivation for TinTin

- High Precision Industrial Communication Systems: designed with extreme care and redundancy
  - The traffic profiles are well-defined and structured.
  - Most of the traffic consists of ‘commands’ and is low volume
- Main goal: design a transport protocol for industrial devices that are:
  - Constrained with limited CPU and RAM capability
  - Not power constrained
- Assumption: communication medium is not prone to interference
  - there are no packet losses due to interference in the medium
- Property: relies on and leverages evolving new network technologies
    - For example: New IP

TinTin Protocol Design

Design Overview and Principles

- Adopts a modular approach
  - Both long and short protocol control headers are supported
- Supports features that are suitable for industrial networks:
  - Closed-control loop
  - Publish/Subscribe messages
  - Time-centric packet delivery
- Assumption: high precision communication network is available to support time-based end-to-end delivery.
- A lightweight transport protocol with time-aware network characteristics
  - Uses a 'magic token' instead of source/destination ports
  - TinTin control header introduces a 'message-type' concept

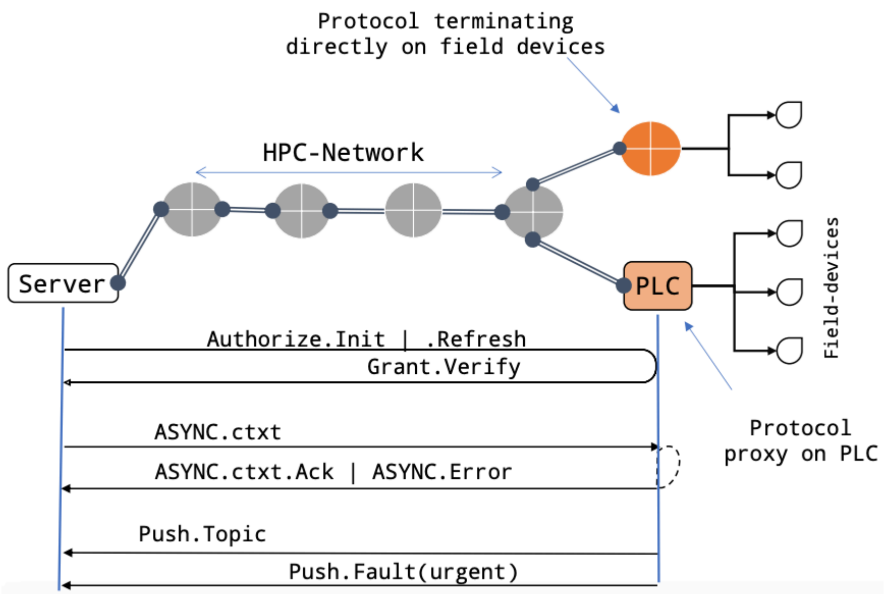
Design Overview and Principles (contd ...)

- Key considerations of TinTin protocol:
  - *Packet Delivery*: connectionless protocol with application driven reliability, modular choice of long/short headers
  - *Enhanced Reliability*: due to additional time based parameters provided by TinTin, does not send an ACK unless requested
  - *Congestion Control*: industrial networks are well managed, so TinTin relies on the network to handle congestion or expects pacing at the server side
  - *Packet Ordering*: notion of a flow is not necessary in IIoT, most of the messages contain short commands, sequence numbers are provided to maintain ‘order among a group of commands’.

Design Overview and Principles (contd …)

- Key considerations of TinTin protocol (contd …):
  - *Dealing with Packet losses*:
    - ➡ physical media errors (rely on sender-side timeouts?)
    - ➡ network congestion (in-network support to handle congestion?)
    - ➡ connectivity-loss/non-reachability (heart beats from application?)
    - ➡ failures on the receiving side (isolate the end device?)
  - *Dealing with Pub/Sub Pattern*: broker-free end-to-end communication by using asymmetric and semantic addressing structures

High-Level Architecture



TinTin Architecture and Communication Model

Terminology:

- ❑ TinTin Endpoint: field-devices, application servers or controllers
- ❑ Authorized node: that is verified and granted access to by a field device
- ❑ TinTin Protocol Data Unit (T-PDU): the transport control header of TinTin
- ❑ Payload: service or application data in T-PDU

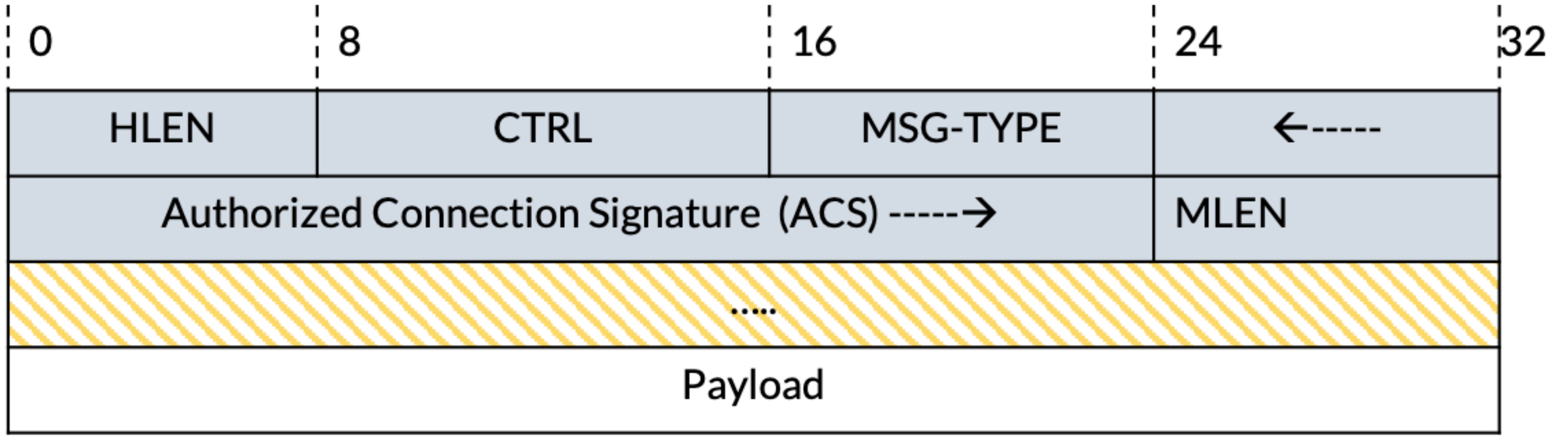
Protocol Operations

Three top-level pairs of directive(s):

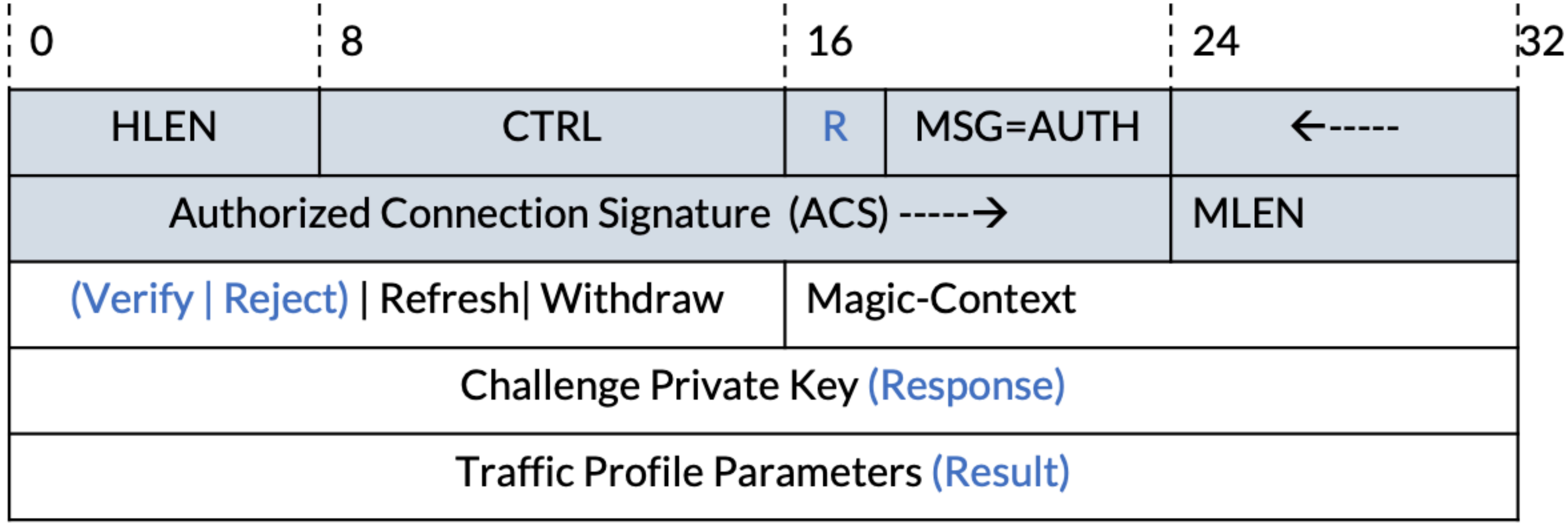
- ❑ Authorize & Grant
- ❑ Async & Reply
- ❑ Post

Minimal Header Fields:

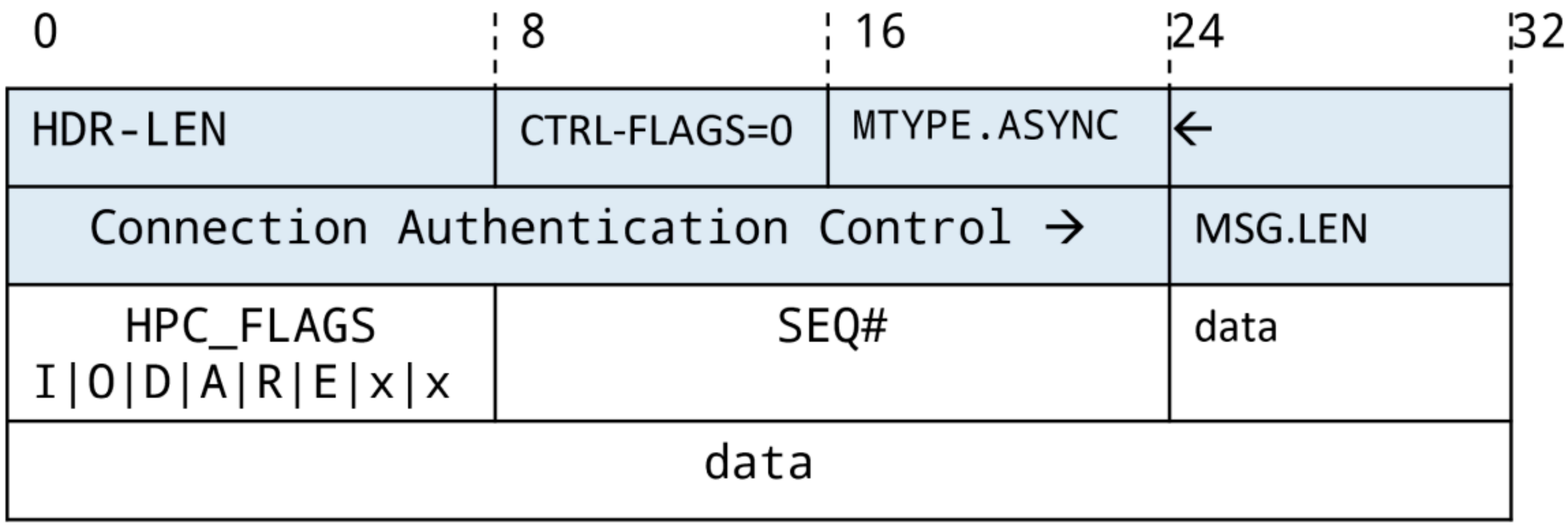
- ❑ ACS: Application Connection Signature
- ❑ CTRL: placeholder for specific extension flags or to indicate length of ACS



Directives



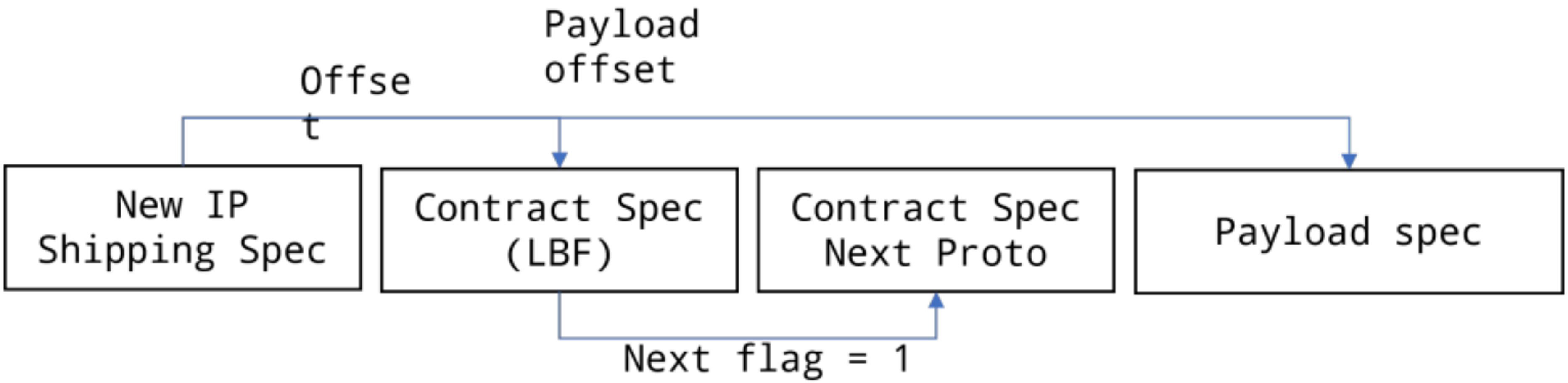
Authorize and Async Headers



Aysnc Header for time-based transmission

TinTin Implementation Details

TinTin with Time-Aware Network (New IP)



- ❑ Next Proto is TinTin in this case
- ❑ It is used alongside a contract that provides high precision services
  - Latency Based Forwarding (LBF)
- ❑ Fundamental operations of TinTin have been tested using NeST
  - Spins off a custom topology using Linux network namespaces
  - TinTin is implemented in the controller and field device sides

Conclusions and Future Work

Conclusions and Future Work

- Conclusions
  - Preliminary work on high precision transport protocol: TinTin
  - It is a promising first step in filling one of the critical gaps in IIoT
  - Headers are shorter than existing transports, such as TCP and UDP
  - Its security-centric design with ephemeral identifiers enhances security of end-to-end communications
  - TinTin also builds on programmable, extensible header philosophy
  - Testing: all time-specific requirements met by using a LBF contract
- Future Work
  - Develop a realistic test environment to evaluate each message in more details with specific focus on reliability

Thank you!