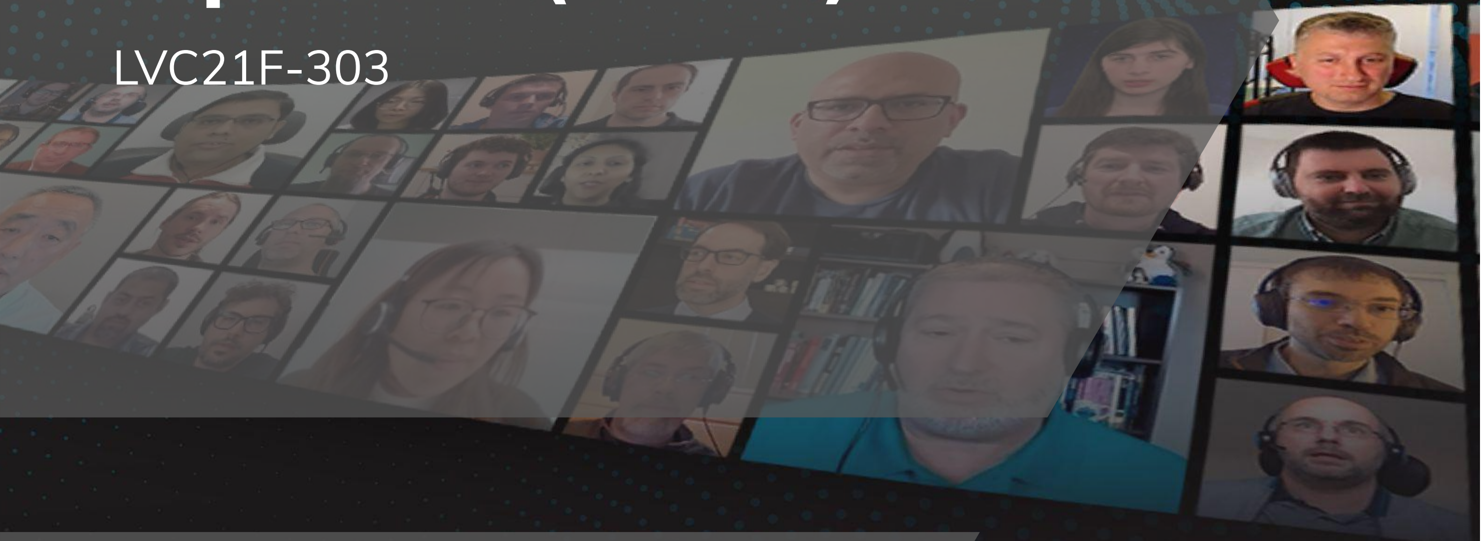
Secure Telemetry Pipeline (STeP)

LVC21F-303



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What is STeP?

- **S**ecure **Te**lemetry **P**ipeline

- Proof of concept to process telemetry data in a flexible pipeline for secure systems

- PoC Provided as a **Zephyr module**:
  - Written in C
  - Flexible unit test framework
  - Can be run in QEMU
  - Supports sensor emulation

- Core concepts should be easy to port to other languages or platforms

Available on Github:
github.com/microbuilder/linaro_sensor_pipeline

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Why STeP?

Telemetry data needs to be **represented**:

- **Concisely**
  (Embedded = small)
- **Unambiguously**
  (Clear SI units, scales and C types)
- **Precisely**
  (Optimal use of limited bits)
- **Generically**
  (Accommodate any measurement)
- **Flexibly**
  (Ability to account for the unknown)

Data **processing** needs to account for:

- Complex workflows
- Fundamental transformations
  - Basic DSP, filtering, fusion, etc.
- Security
  - Integrity (hashing)
  - Provenance (signing)
  - Secrecy (encryption)
- Limited resources
  - Data compression
  - Efficient use of memory
- Bonus: Easy code reuse

Why STeP?

STeP aims to address these two problems by:

- Representing **measurements** efficiently, unambiguously and precisely

- Implementing a **node-based pipeline** for async processing of measurements:
    - **Processor nodes** can be **chained** together in an specific order
    - They are registered into a central **node registry**
    - Registered nodes fire based on **filter matches** between the node and measurement
    - Speciality nodes can be **reused** across measurement types, acting like building blocks
    - Measurements are processed efficiently with **no mem copy** required
    - Optional memory allocation and management from a **shared sample pool**

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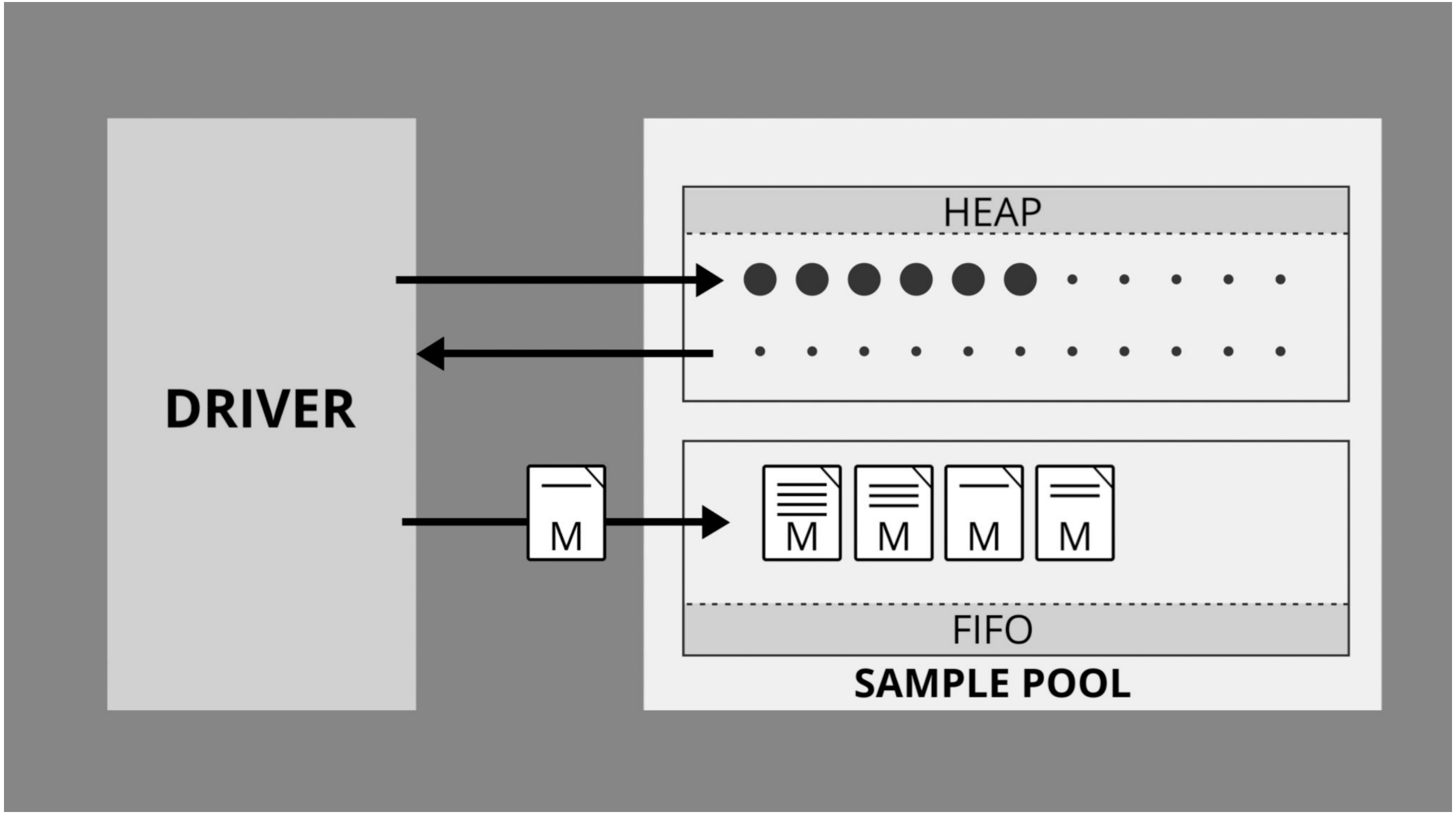
Overview (video)



Measurements

Consists of a **12-byte header**, with an optional timestamp:

- Filter →
- Unit Type and Scale →
- Source and Length →
- Timestamp (Optional) →
- Payload (64KB max) →

```
 3                   2                   1
 1 0 9 8 7 6 5 4 3 2 1 0 9 8 7 6 5 4 3 2 1 0 9 8 7 6 5 4 3 2 1 0
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|             Flags             | Ext. M Type   | Base M Type   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|    C Type     | Scale Factor  |          SI Unit Type         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   Source ID   | S Cnt | V | F |         Payload Length        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                     Timestamp (optional)                      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
|                            Payload                            |
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

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Filter Word

- Filter Word

```
  3                   2                   1
 1 0 9 8 7 6 5 4 3 2 1 0 9 8 7 6 5 4 3 2 1 0 9 8 7 6 5 4 3 2 1 0
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|             Flags             | Ext. M Type   | Base M Type   |
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|    C Type     | Scale Factor  |          SI Unit Type         |
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|   Source ID   | S Cnt | V | F |          Payload Length       |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                      Timestamp (optional)                     |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
|                            Payload                            |
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

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Filter Word: Measurement Type

Measurements are categorised using an 8-bit **Base Measurement Type** and an optional 8-bit **Extended Measurement Type**.

This allows for **flexible** but **precise** expression of nearly any measurement type.

Base types provide high level groups:

- ACCELERATION
- ENERGY
- LIGHT
- MASS
- TIME
- VELOCITY

Extended types specialise base types:

- LIGHT_RADIO_RADIANT_FLUX
- LIGHT_RADIO_IRRADIANCE
- LIGHT_PHOTO_LUM_FLUX
- LIGHT_PHOTO_LUM_INTEN
- LIGHT_PHOTO_ILLUMINANCE

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Filter Word: Flags

- **Data Format**
  Indicates if the payload is unformatted value, CBOR data, etc.
- **Encoding**
  Indicates optional payload encoding for transmission
- **Compression**
  Algorithm used if payload is compressed (LZ4, etc.)
- **Timestamp**
  Indicates if present, and what format (epoch32, ms since boot, etc.)

```
                    1
 5 4 3 2 1 0 9 8 7 6 5 4 3 2 1 0
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Res | TSt | CMP | Encod |  DF | <- Flags
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
      |     |     |     |     |
      |     |     |     |     +-------- Data Format (CBOR, etc.)
      |     |     |     +-------------- Encoding (BASE64, BASE45)
      |     |     +-------------------- Compression (LZ4, etc.)
      |     +-------------------------- Timestamp Type
      +-------------------------------- Reserved
```

Filter Word

Measurement type + Flags = a 32-bit word called the **FILTER** value.

- This word contains key details of the measurement **contents** and **format**.
- When measurements are processed, the **FILTER** value is validated against a set of IS/NOT/AND/OR/XOR rules to see if there is a match. Ex:
  - Measurement matches if filter:
    - Base Type = STEP_MES_TYPE_TEMPERATURE
    - Extended Type = STEP_MES_EXT_TYPE_TEMP_DIE **OR** STEP_MES_EXT_TYPE_TEMP_AMBIENT
    - Format = STEP_MES_FORMAT_CBOR
    - Timestamp = STEP_MES_TIMESTAMP_UPTIME_MS_32 **OR** STEP_MES_TIMESTAMP_UPTIME_MS_64
- If a match occurs, that measurement will be processed by that processor node or node chain.

Unit Type and Scale

- Unit Type and Scale →

```
 3                   2                   1
 1 0 9 8 7 6 5 4 3 2 1 0 9 8 7 6 5 4 3 2 1 0 9 8 7 6 5 4 3 2 1 0
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|              Flags                |  Ext. M Type  |  Base M Type  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     C Type    | Scale Factor  |          SI Unit Type             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   Source ID   | S Cnt | V | F |          Payload Length           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                       Timestamp (optional)                        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                                   |
|                              Payload                              |
|                                                                   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

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Unit Type and Scale

Not exhaustive!

SI Unit Type

'What' is being represented

- SI Base Unit
  - SI_KELVIN
- SI Derived Unit
  - SI_DEGREE_CELSIUS
- SI Combined Unit
  - SI_SIEMENS_PER_METER

SI Scale Factor

- Default scale can be overridden via **scale factor** (A → mA = -3)

C Memory Type

'How' it is represented in memory

- CTYPE_IEEE754_FLOAT32
- CTYPE_IEEE754_FLOAT64
- CTYPE_S32
- CTYPE_U64
- CTYPE_COMPLEX_32
- CTYPE_RANG_PERCENT_32
- User-defined options

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Source ID and Length

- Source and Length →

```
 3                   2                   1
 1 0 9 8 7 6 5 4 3 2 1 0 9 8 7 6 5 4 3 2 1 0 9 8 7 6 5 4 3 2 1 0
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|              Flags            |  Ext. M Type  |  Base M Type  |
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|     C Type    | Scale Factor  |          SI Unit Type         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   Source ID   | S Cnt | V | F |        Payload Length         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                      Timestamp (optional)                     |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
|                            Payload                            |
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Source ID and Length

Payload Length

16-bit value, with up to 65536 bytes (minus header, including timestamp)

Fragment (F)

Indicates that this payload extends over more than one 64 KB payload

Vector Size (V)

Indicates that this is a vector (rather than a scalar) value, composed of vect_sz + 1 components (accel triplet, quaternion, etc.)

Sample Count (S Cnt)

Indicates the number of distinct samples in the payload, as $count^2$, with an option to insert an arbitrary count.

Multiple samples in one measurement payload allows more efficient memory use and processing.

Source ID

An 8-bit ID to correlate measurements with a source device during later processing.

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Timestamp

- Timestamp (Optional) →

```
 3                   2                   1
 1 0 9 8 7 6 5 4 3 2 1 0 9 8 7 6 5 4 3 2 1 0 9 8 7 6 5 4 3 2 1 0
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|               Flags               |  Ext. M Type  |  Base M Type  |
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|   Source ID   | S Cnt | V | F |        Payload Length         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                      Timestamp (optional)                     |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
|                            Payload                            |
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

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Timestamp

Indicates the time that the first sample in the payload was captured using a flexible list of timestamps, depending on what resources are available on the MCU.

NOTE: If multiple measurements are included in the payload, the stride between samples will need to be communicated out of band.

Current timestamp options are:

- TIMESTAMP_NONE
- TIMESTAMP_EPOCH_32
- TIMESTAMP_EPOCH_64
- TIMESTAMP_UPTIME_MS_32
- TIMESTAMP_UPTIME_MS_64
- TIMESTAMP_UPTIME_US_64

Payload

- Payload (64KB max) →

```
  3                   2                   1
 1 0 9 8 7 6 5 4 3 2 1 0 9 8 7 6 5 4 3 2 1 0 9 8 7 6 5 4 3 2 1 0
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
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+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                      Timestamp (optional)                       |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
|                            Payload                            |
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Payload

Depending on the **flags** in the header, the payload can either be one or more raw samples in the specific C type (and depth if the **vector** field in used), or can be an CBOR encoded payload, encrypted data, etc.

The exact contents depends on the header, with the only restriction being that each individual payload is limited to 64 KB.

The payload contents can and often will change as measurements are processed!

Be sure to allocate a payload of sufficient size to take into account all of the processing requirements of the pipeline, such as encoding to BASE64, or the overhead of signing and hashing payloads.

Processor Nodes

Nodes act a **mini applications**, that act upon incoming measurement packets.

They allow you to encapsulate (and reuse) specific, common processing logic such as filtering, hashing and signing, encrypting, compressed, encoding, etc.

Writing a node once should make it trivial to reuse the logic with minor variations.

Processor nodes ...

- can be linked into **node chains** (filter match based on first node)
- are **destructive** (they operate on the incoming message, not a copy)!
- have **priority lvl** for execution order
- Have complex **filter match** support
- are based on a series of callbacks:
  - Init
  - Evaluate (complex filter match)
  - Matched
  - Start
  - Execute
  - Stop
  - Error

Processor Node Registry

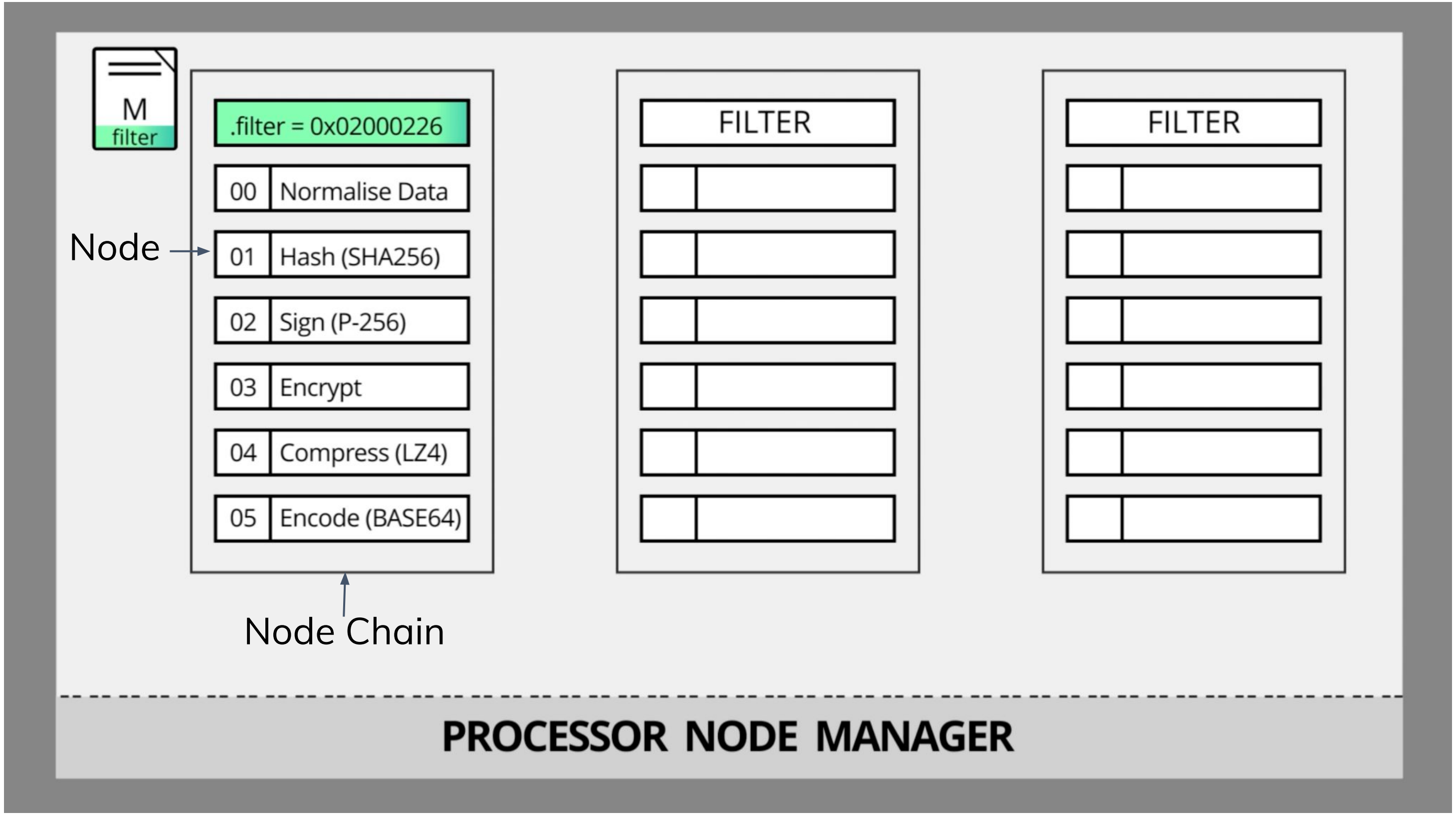
The **Processor Node Manager** maintains an internal **registry** of active nodes or node chains.

Incoming measurements are executed again all nodes or node chains in the registry in order of **used-defined priority**.

Nodes can have complex **filter chains** to determine which measurements the process (IS, NOT, AND, OR, XOR), or evaluate complex cases in a callback.

- Records in the registry can be dynamically enabled/disabled at runtime, and new records can be added/removed/updated.

Processor Registry (video)



Future Work

- Integration into a secure service in Trusted Firmware-M
- Implement TF-M backed nodes for common security considerations:
  - Signing
  - Hashing
  - Encryption/Decryption
- End to end workflow with simulated sensor data for CI, testing
- Improve throughput

Feedback and questions

- https://github.com/microbuilder/linaro_sensor_pipeline
- kevin.townsend@linaro.org

Thank you

Accelerating deployment in the Arm Ecosystem

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