

RDF Provisioning for the Internet of Things

Henning Hasemann, Alexander Kröller, Max Pagel
TU Braunschweig

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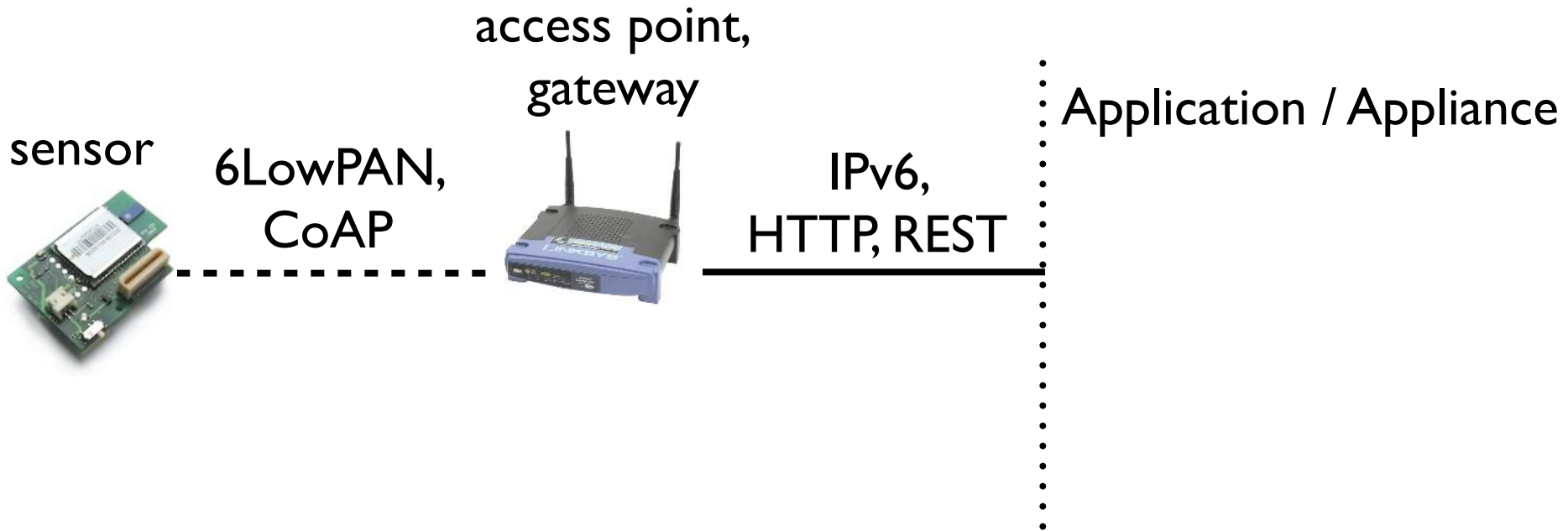
The world as it should be

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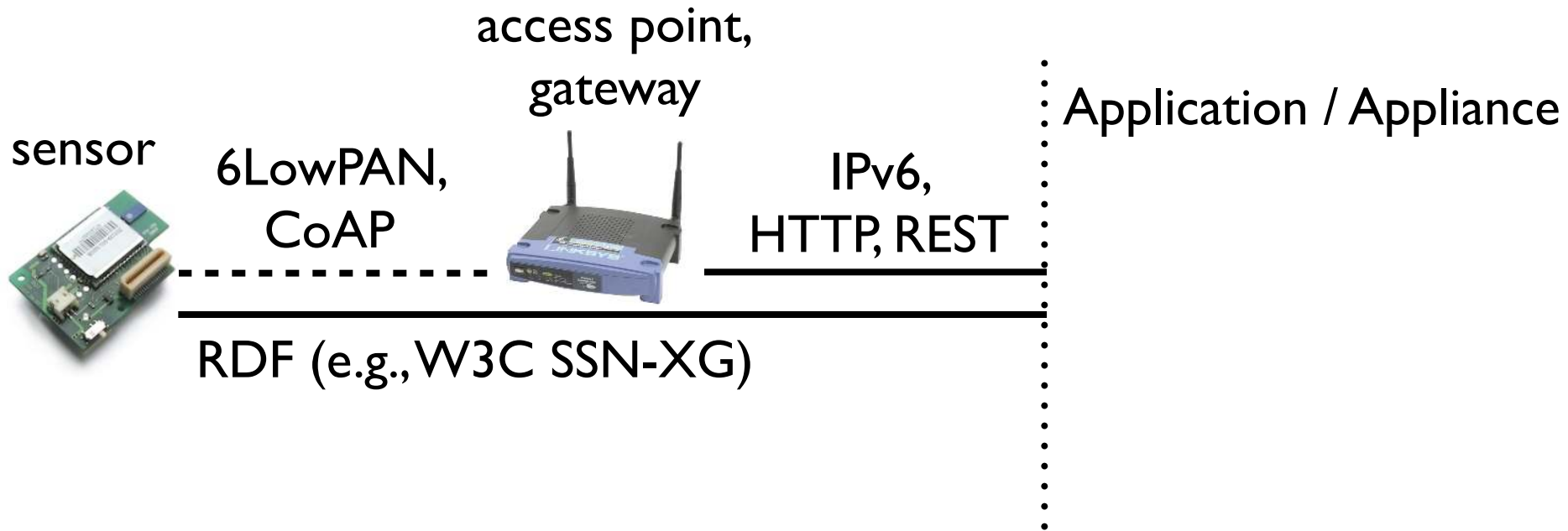
sensor



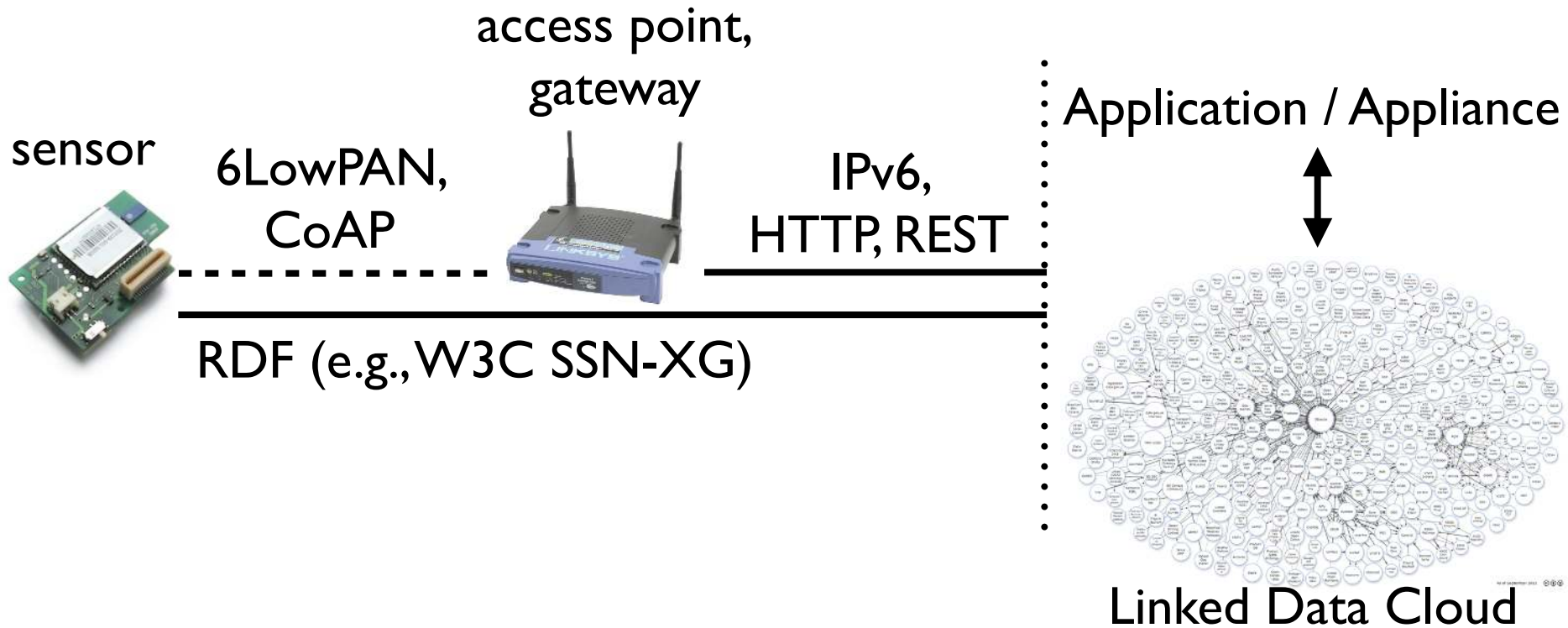
The world as it should be



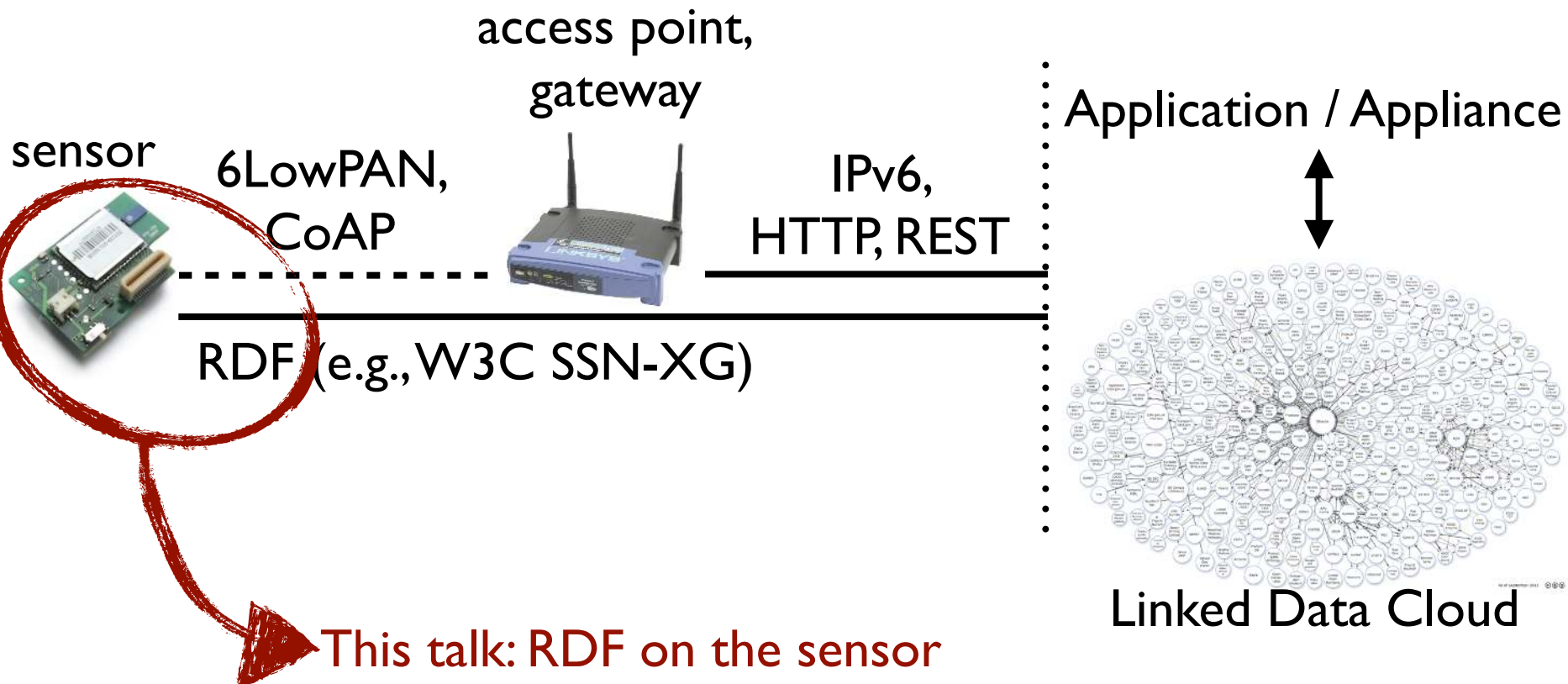
The world as it should be



The world as it should be



The world as it should be



RDF represents facts as *subject–predicate–object* triples:

sensor01 hasValue 22.7

W3C **SSN-XG** ontology for sensors (SensorML superset)

Plus: Data can be linked to arbitrary other datasets. Works with closed data too!



Goal: Sensor “is” a self-rewriting RDF document:

```
▼<rdf:Description rdf:about="http://spitfire.ibr.cs.tu-bs.de/be-0001/b4ec27c5-d543-496a-b2bf-a960134dcb37/2/sensor#sensor">
  <j.2:hasValue rdf:datatype="http://www.w3.org/2001/XMLSchema#double">22.7</j.2:hasValue>
  <j.2:hasLocation rdf:resource="http://sws.geonames.org/2945024" />
  <j.2:hasLocation rdf:resource="http://rooms-bs.sytes.net/static/descriptions#Room4" />
  <j.0:date>10.10.2012 20:15:00</j.0:date>
  <j.4:hasMeasurementCapability rdf:resource="http://spitfire.ibr.cs.tu-bs.de/be-0001/b4ec27c5-d543-496a-b2bf-a960134dcb37/2/sensor#measurementCapability" />
  <j.4:featureOfInterest rdf:resource="http://rooms-bs.sytes.net/static/descriptions#Room4" />
  <rdf:type rdf:resource="http://spitfire.ibr.cs.tu-bs.de/static/descriptions#VolumeSensor" />
</rdf:Description>
```



Typical sensor (Jennic-based iSense):

- Specialized firmware (or Contiki, TinyOS etc)
- IEEE 802.15.4 radio (no direct IP connectivity)
- ~100kB of RAM shared for code, heap, data
- No external flash. No filesystem.



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 - **efficient** (data storage)

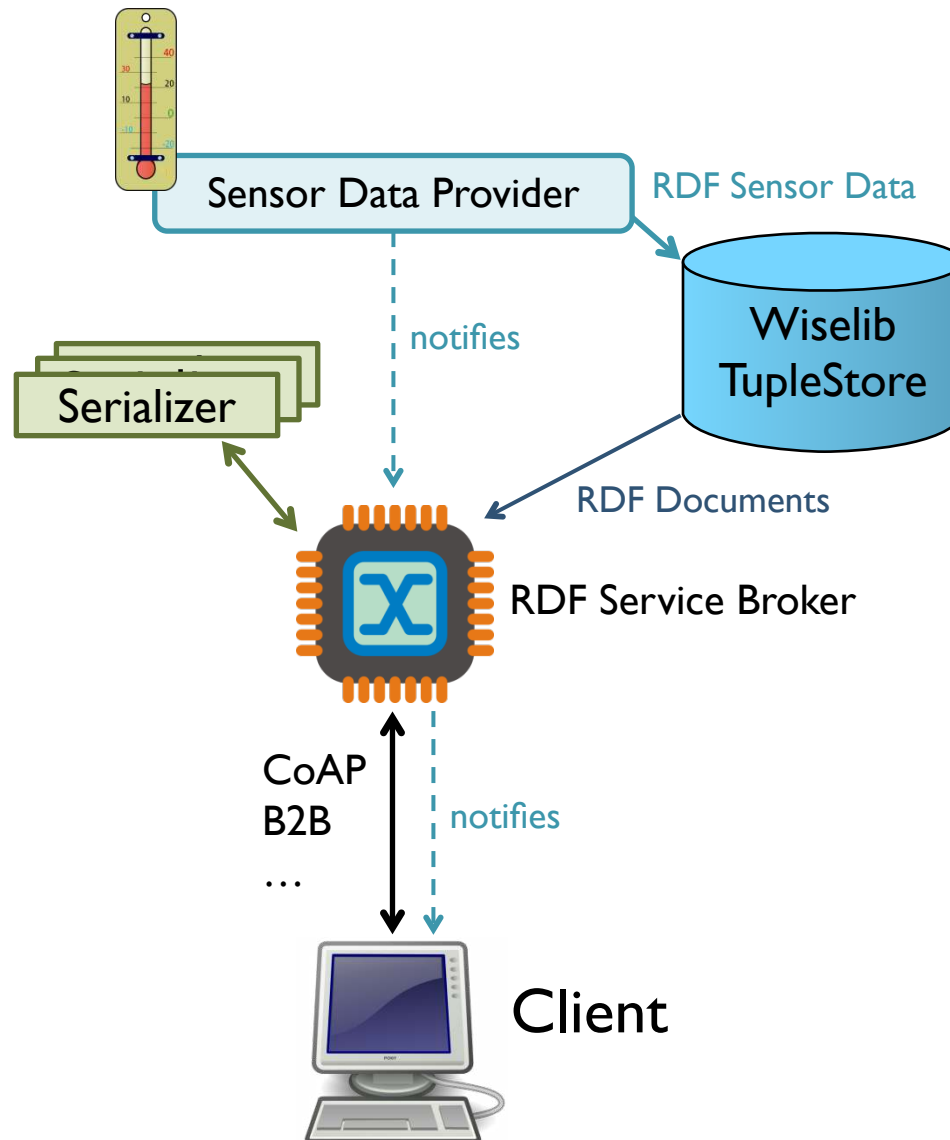


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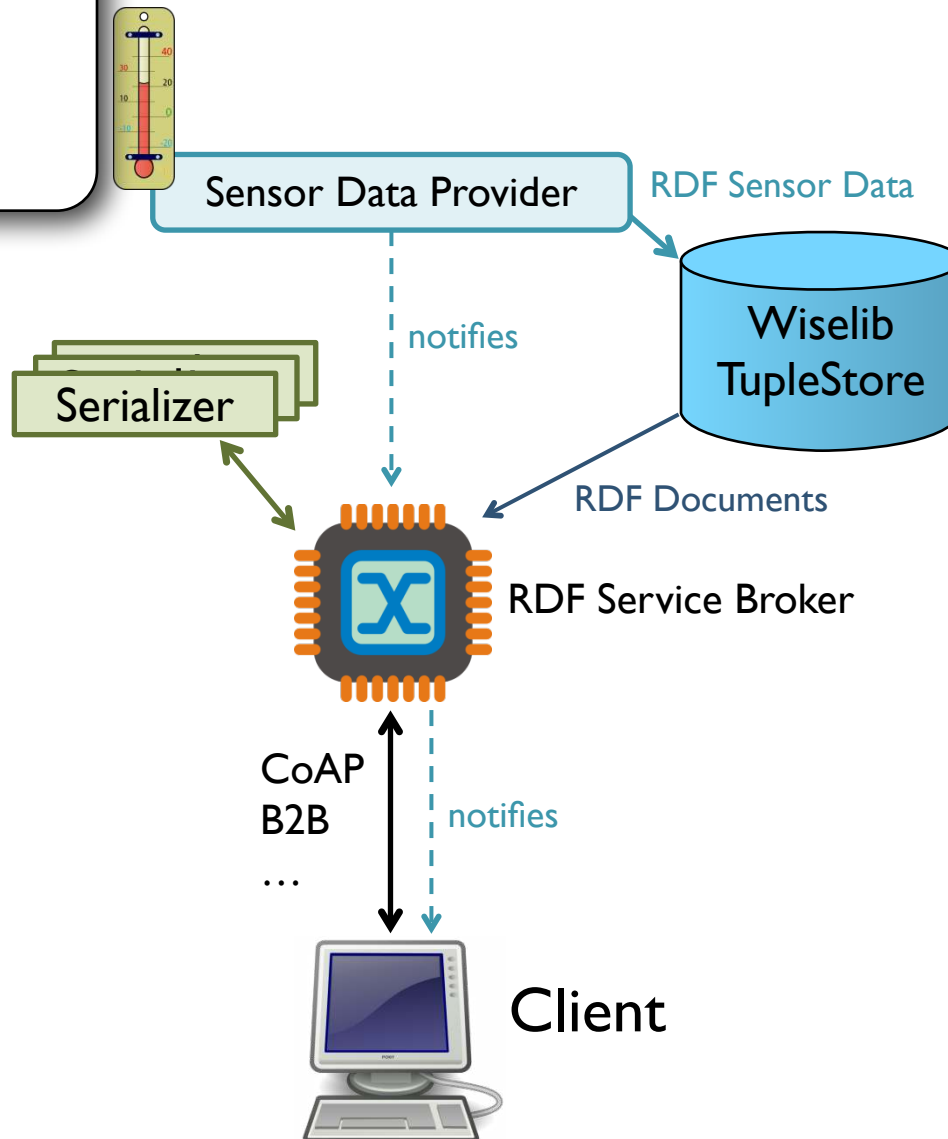
- Solution needs to be
- **efficient** (code size)
 - **efficient** (communications)
 - **efficient** (data storage)
 - **platform-independent**

The Wiselib RDF Provider



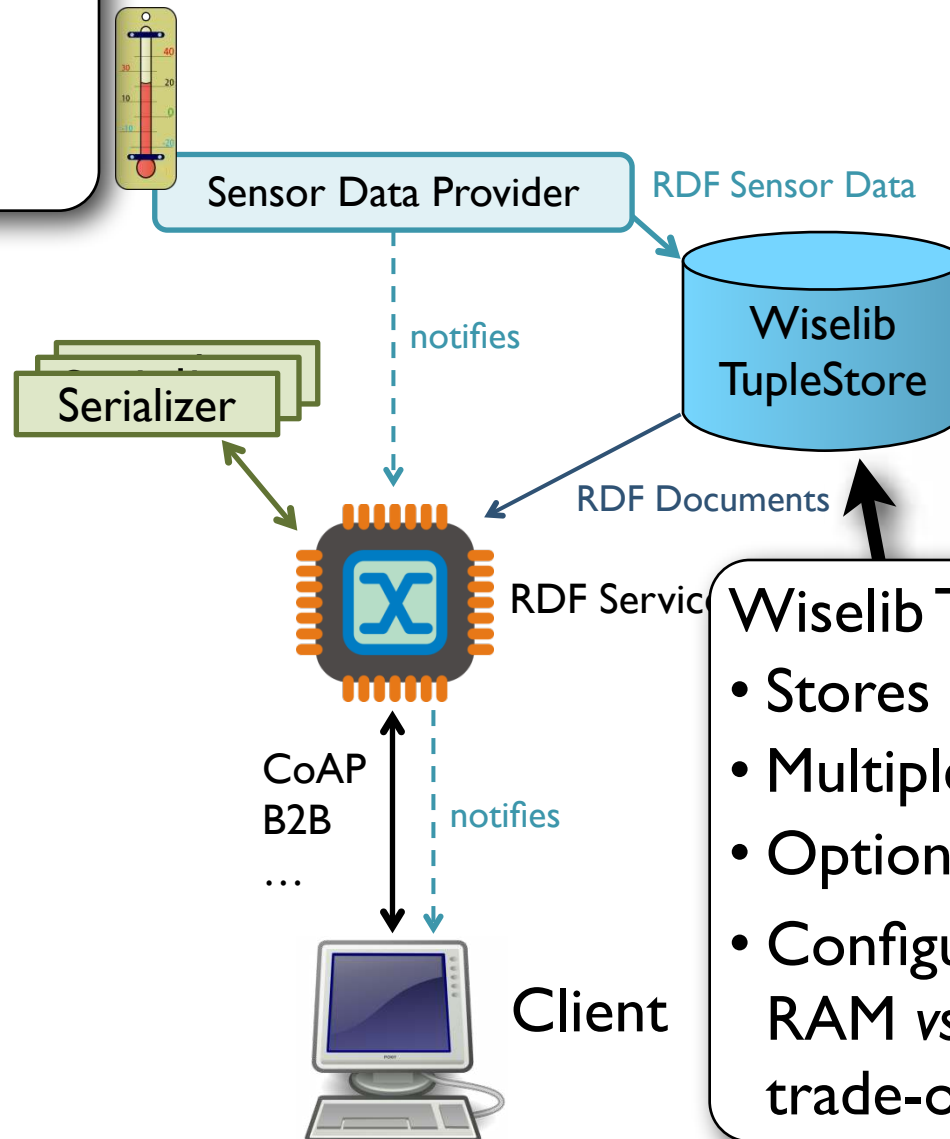
The Wiselib RDF Provider

Based on the Wiselib:
compiles for 10+
platforms,
efficient C++



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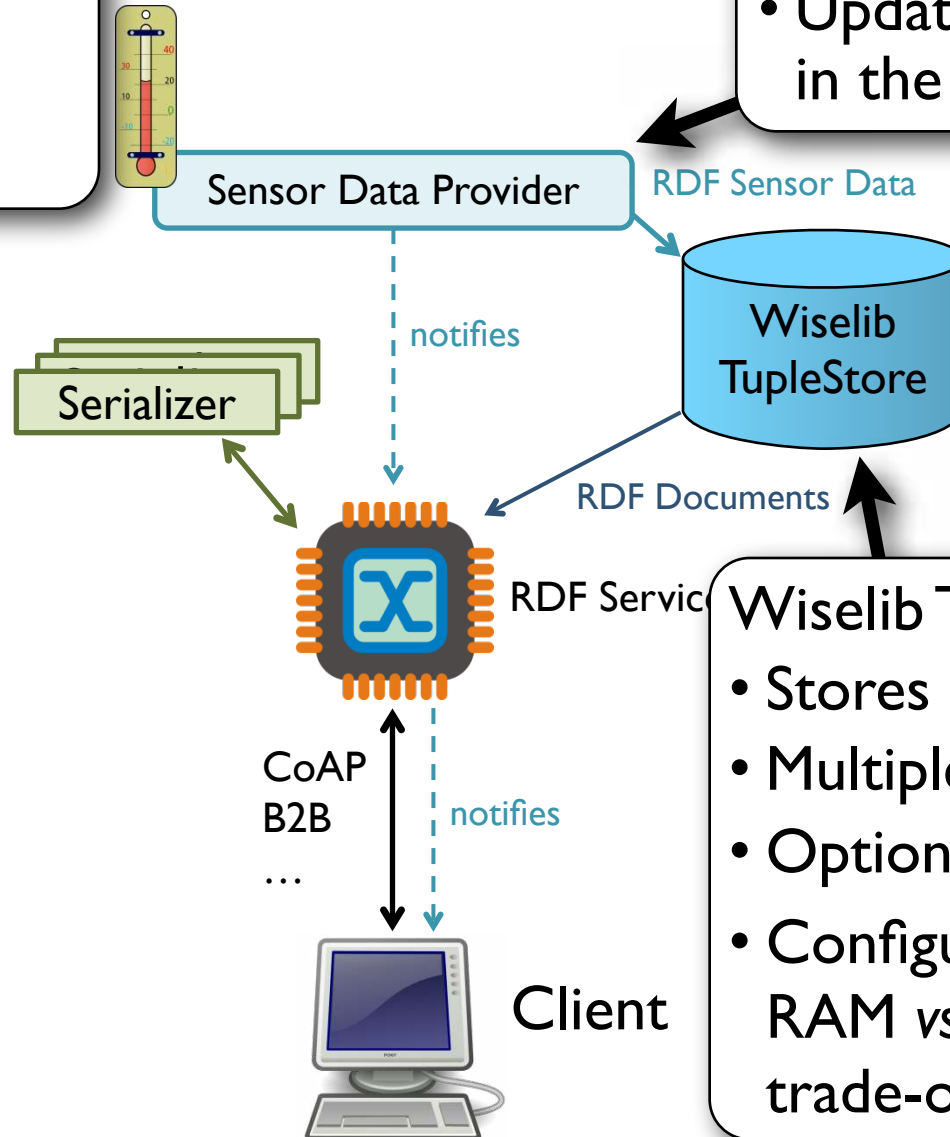


Wiselib TupleStore

- Stores RDF triples
- Multiple documents
- Optional compression
- Configurable code vs. RAM vs. energy trade-offs

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Based on the Wiselib:
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Sensor Data Provider
• Updates sensor data
in the TS

Wiselib TupleStore
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Sensor Data Provider

Sensor Data Provider
• Updates sensor data
in the TS

RDF Sensor Data

Wiselib
TupleStore

notifies

Serializer

RDF Documents

RDF Service

Wiselib TupleStore

• Stores RDF triples
• Multiple documents
• Optional compression
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RAM vs. energy
trade-offs

Service Broker

• Provides document-
level access
• Manages notifications

CoAP
B2B
...

notifies



Client

Application - Documents

Represent device with multiple RDF documents
(TupleStore handles repetition)

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Documents per device:



NODE

(device description)



.well-known

(list of documents, services)

Application - Documents

Represent device with multiple RDF documents
(TupleStore handles repetition)

Documents per device:



NODE

(device description)



.well-known

(list of documents, services)

Documents per sensor:



MINIMAL

(just the reading)



INTRINSIC

(+ basic info)



COMPLETE

(all available info)

Broker Protocols I: B2B Command Interface

- Simplest access: Command Interface, tailored for broker-to-broker communication
- Addresses problem: Tuples usually > 1 MTU
- Element-wise transmission + Command (insert/delete), with transaction logic

Transaction table

Subject	Predicate	Object	Operation
0x2304	0xac48		INSERT
0xab80	0x16c0	0x30b4	
...			

TS Dictionary

0x2304	< http://www.ibr.cs.de.. >
0xac48	< http://www.w3.org/... >
0x1074	„Wiselib RDF Provider“
...	



Document-Level Interface

- operates on RDF documents
- usually CoAP service requests from Internet

Operations:

- GET [*documentID*]
- POST [*documentIDs*] [*tuples*]
- DELETE [*documentID*] [*tuple*]

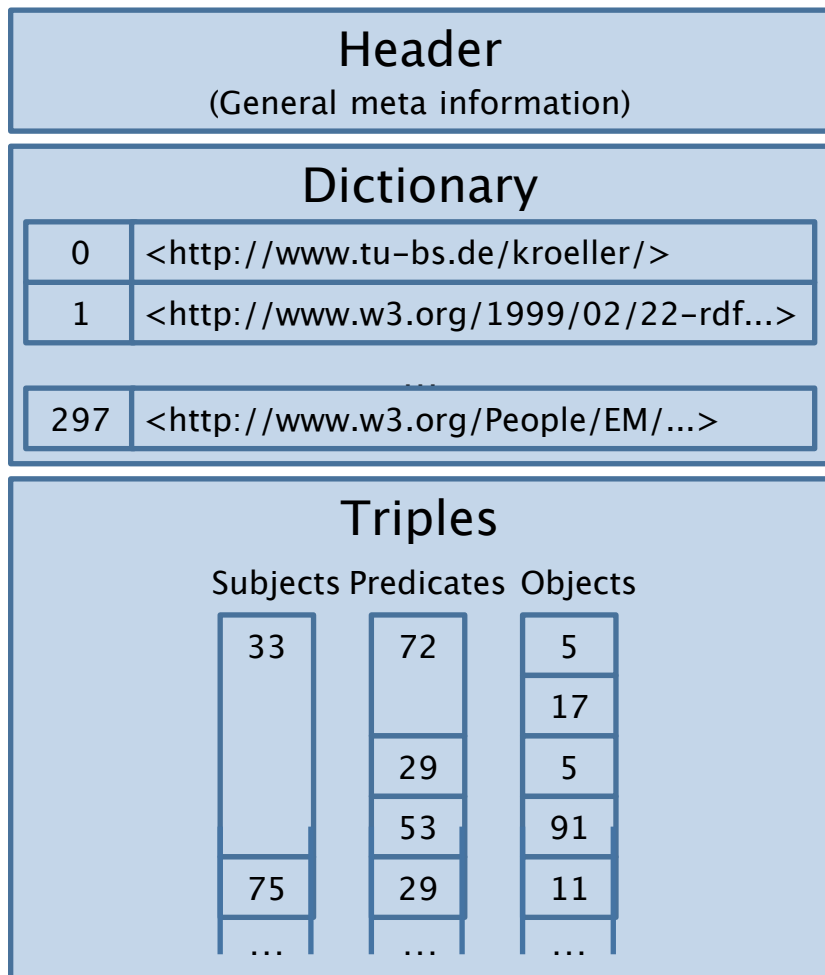
- SUBSCRIBE [*documentID*] [*callback*]
- UNSUBSCRIBE [*subscriptionID*]

Can use different serializations, for now:

Google ProtoBuf and **SHDT**... (RDF-XML too heavy?)

Streaming HDT

HDT [Fernandez et al. '10]

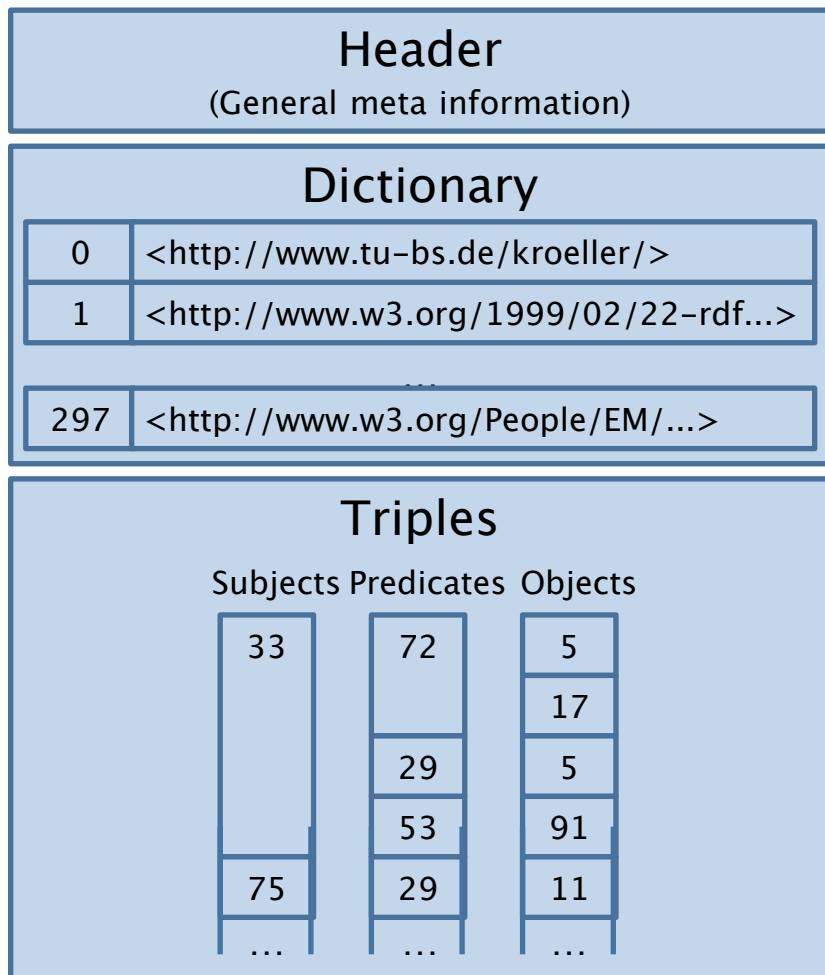


“Header-Dictionary-Triples” (HDT)

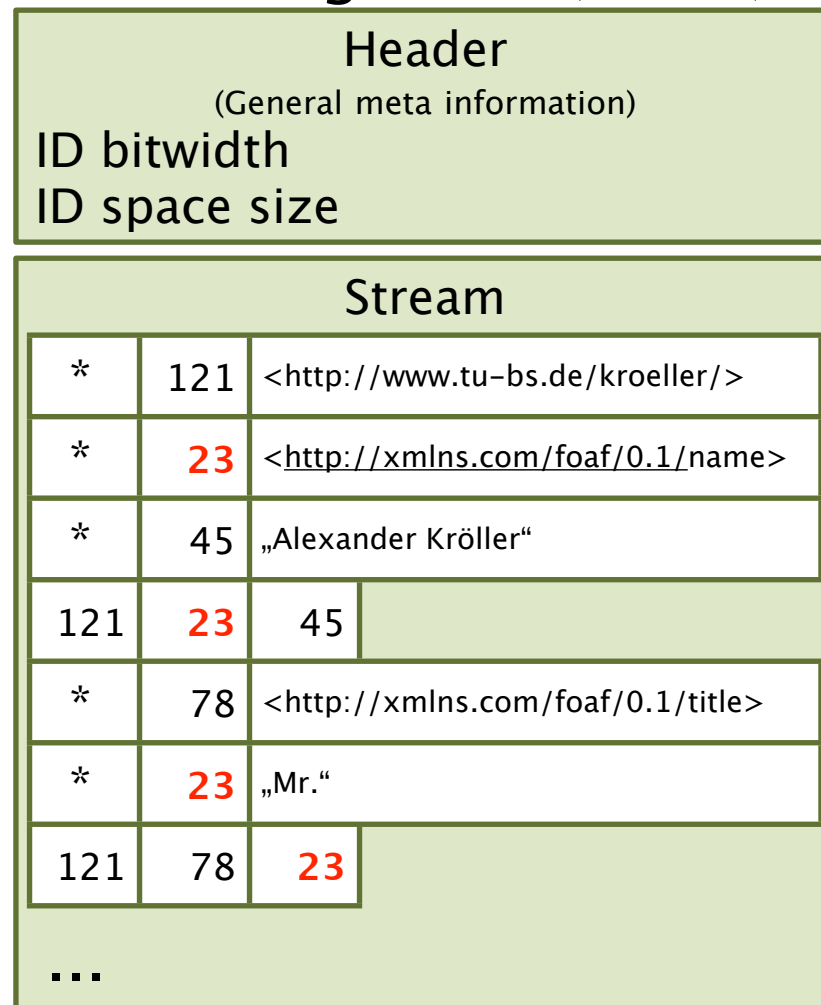
- Standard RDF serialization
- Highly efficient encoding
- **Drawback:** Requires full assembly of document before transmission
≙ halving usable capacity

Streaming HDT

HDT [Fernandez et al. '10]



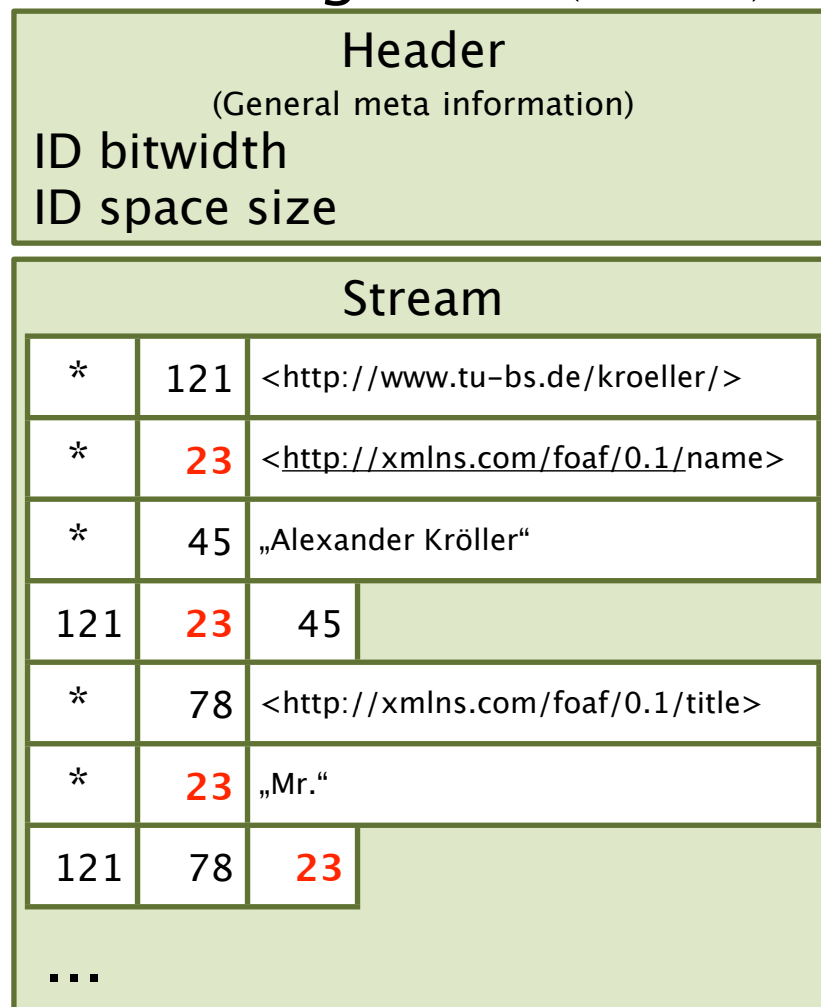
“Streaming” HDT (SHDT)



Streaming HDT

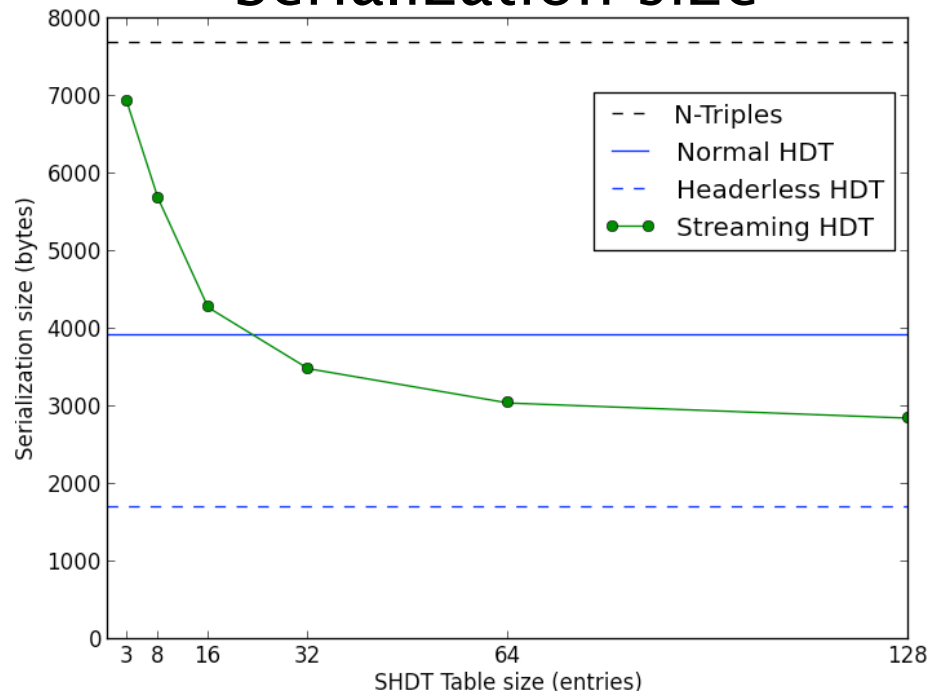
- Document usually transmitted from IoT device (constrained) to Internet host (unconstrained)
- SHDT exploits asymmetry
- *Sender* has freedom to decide ID space, mix dictionary/triples, reuse IDs.
- Allows for encoding on-the-fly, needs buffer for 1 packet plus hash table (any size)

“Streaming” HDT (SHDT)



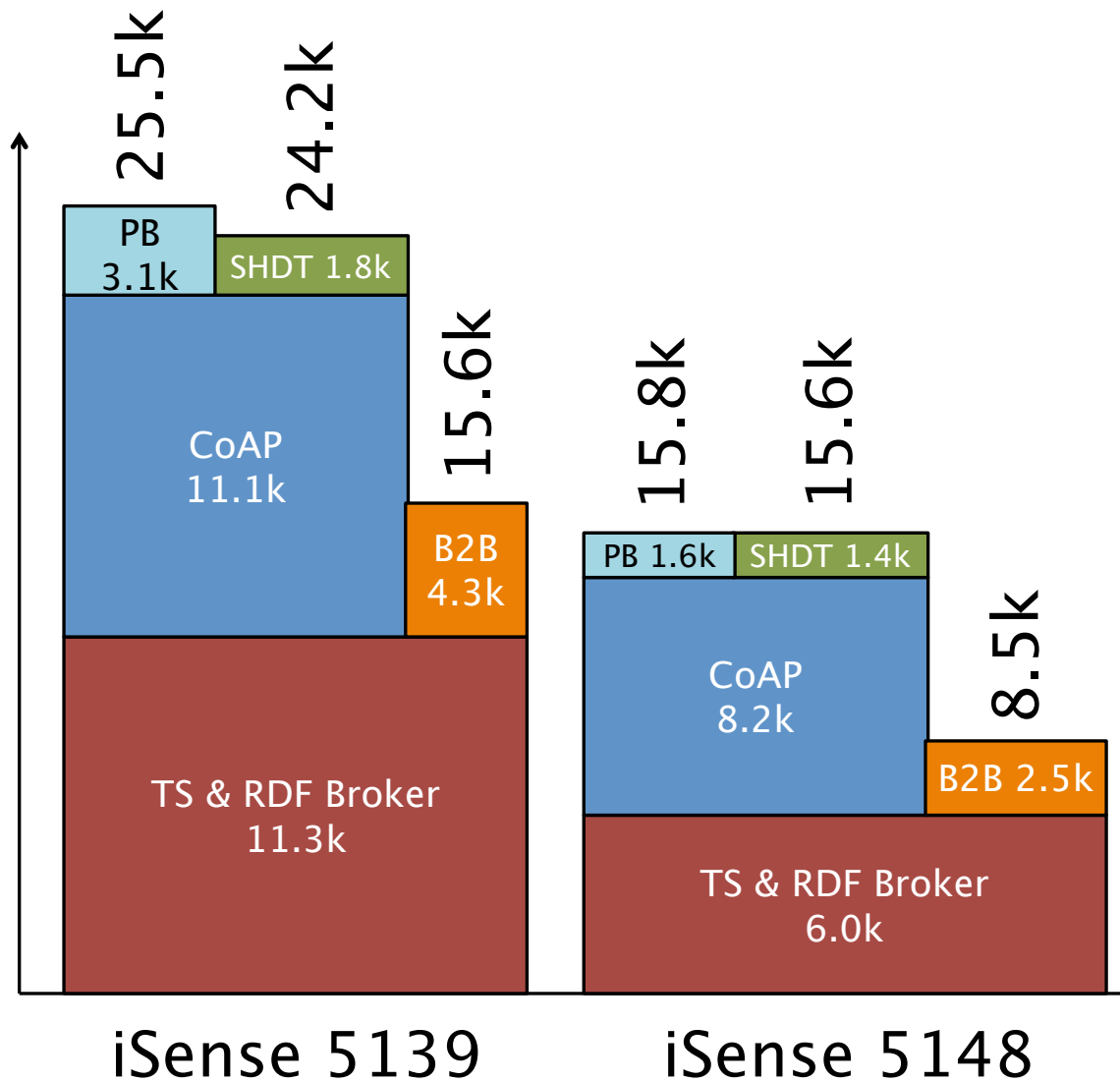
Evaluation – Streaming HDT

Serialization size

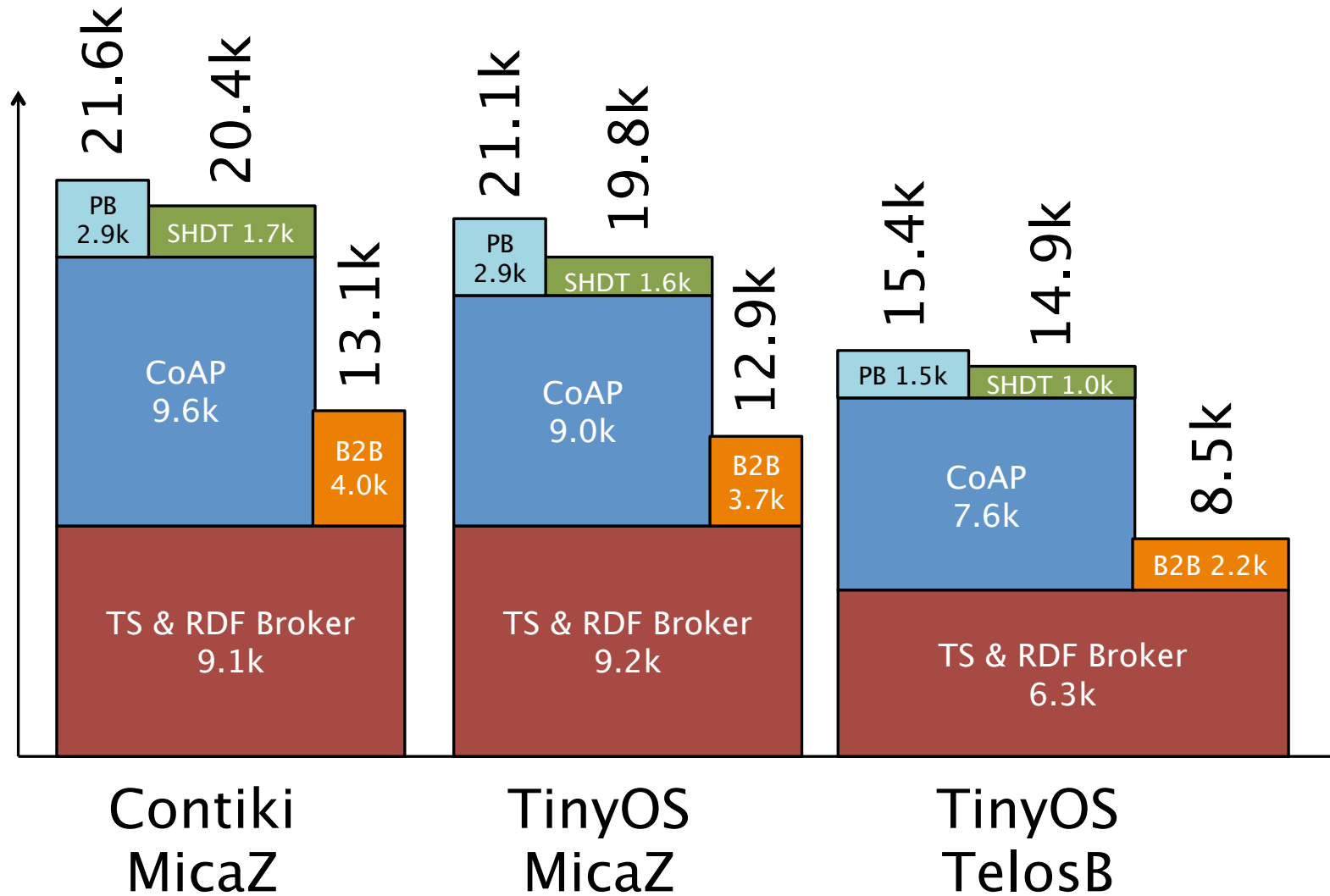


```
<http://spitfire-project.eu/sensor/sensor1234> <http://www.w3.org/2000/01/rdf-schema#type> <http://purl.oclc.org/NET/ssnx/ssn#Sensor> .
<http://spitfire-project.eu/sensor/sensor1234> <http://purl.oclc.org/NET/ssnx/ssn#observedProperty> <http://spitfire-project.eu/property/
Temperature> .
<http://spitfire-project.eu/sensor/sensor1234> <http://spitfire-project.eu/cc/spitfireCC_n3.owl#uomInUse> <http://spitfire-project.eu/uom/
Centigrade> .
<http://spitfire-project.eu/sensor/sensor1234> <http://www.loe-cnr.it/ontologies/DUL.owl#hasValue> "10.2" .
<http://spitfire-project.eu/sensor/sensor1234> <http://purl.org/dc/terms/date> "12-04-02T12:48Z" .
<http://spitfire-project.eu/property/Temperature> <http://www.w3.org/2000/01/rdf-schema#type> <http://purl.oclc.org/NET/ssnx/ssn#Property> .
<http://spitfire-project.eu/property/Temperature> <http://purl.oclc.org/NET/muo/muo#measuredIn> <http://spitfire-project.eu/uom/Centigrade> .
<http://spitfire-project.eu/uom/Centigrade> <http://www.w3.org/2000/01/rdf-schema#type> <http://purl.oclc.org/NET/muo/
muo#UnitOfMeasurement> .
<http://spitfire-project.eu/uom/Centigrade> <http://purl.oclc.org/NET/muo/muo#prefSymbol> "C" .
<http://spitfire-project.eu/sensor/sensor1234> <http://purl.oclc.org/NET/ssnx/ssn#detects> <http://spitfire-project.eu/sensor_stimulus/
silver_expansion> .
...
```

Evaluation — Code Size



Evaluation – Code Size



Contributions & Summary

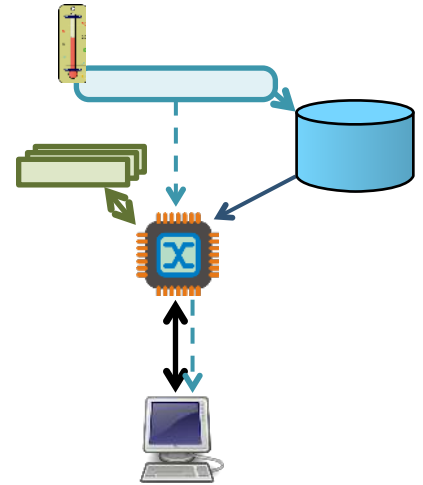


“Node as RDF document”

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- Modular & platform-independent RDF Provider
- Configurable protocols
- Configurable serialization,
+ new SHDT format

Upcoming: External memory data structures (e.g., Flash, SD)



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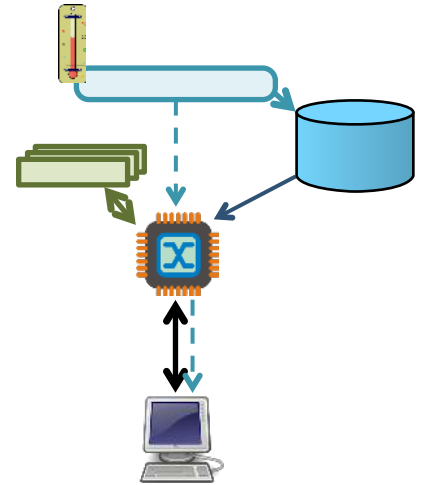


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The End. Thank You!