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

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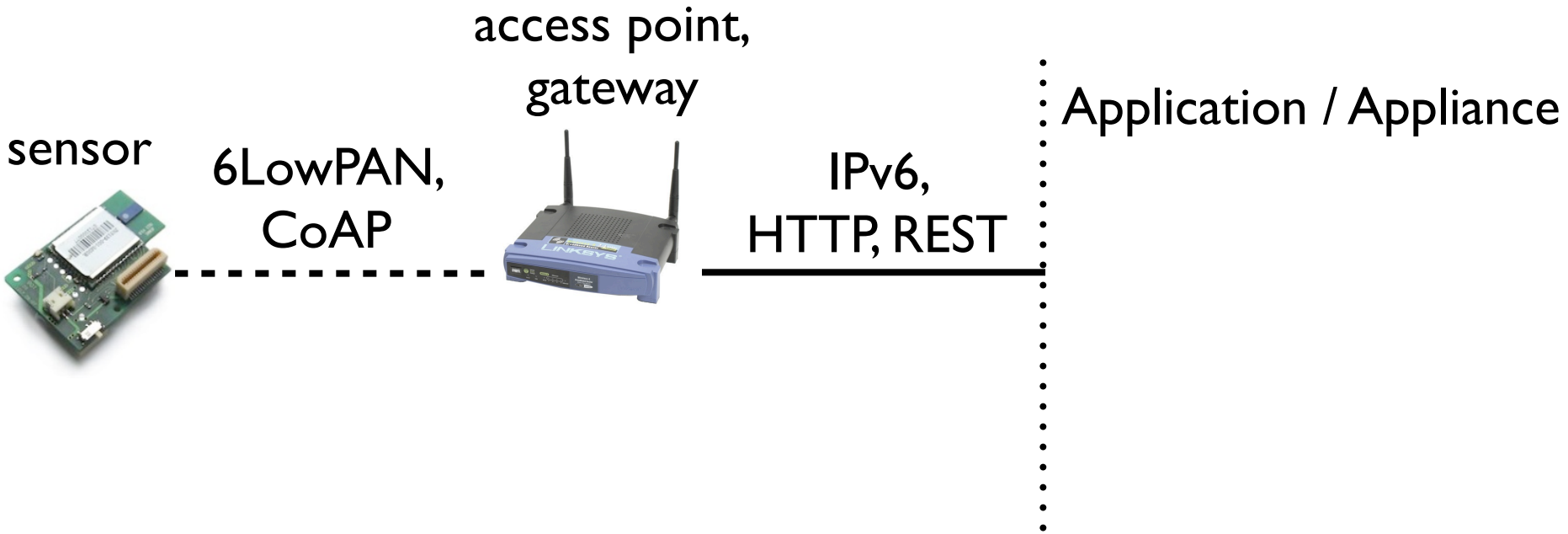
sensor

Application / Appliance

The world as it should be



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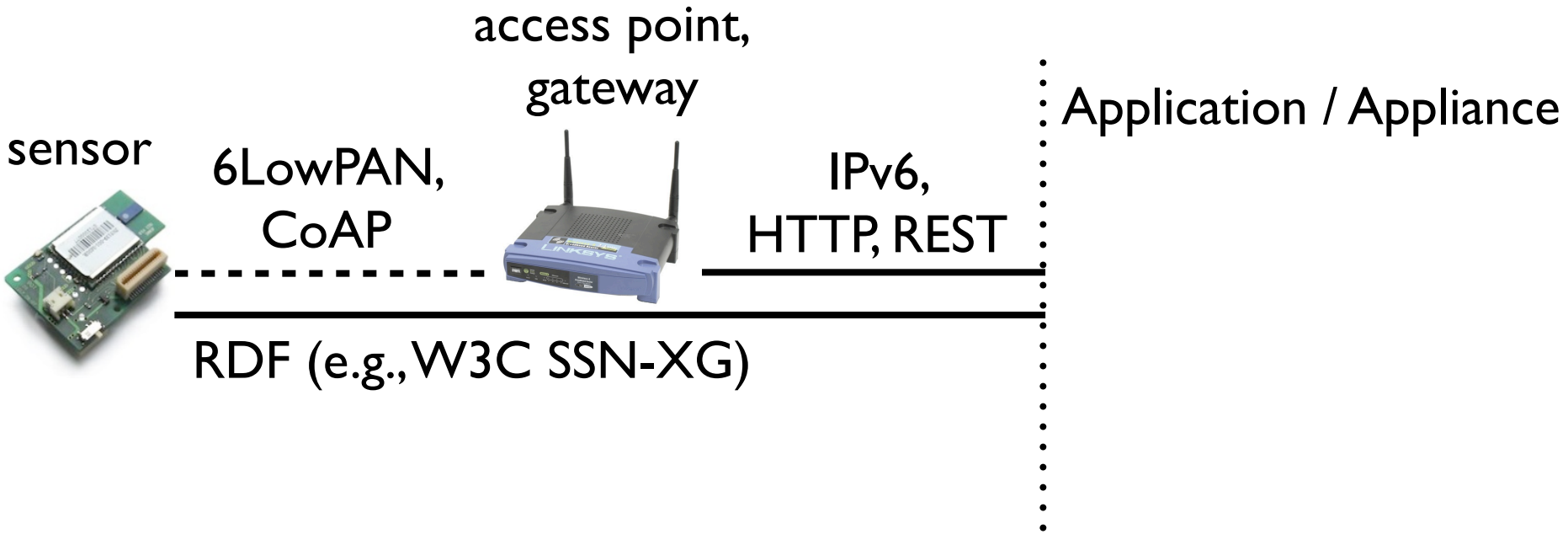

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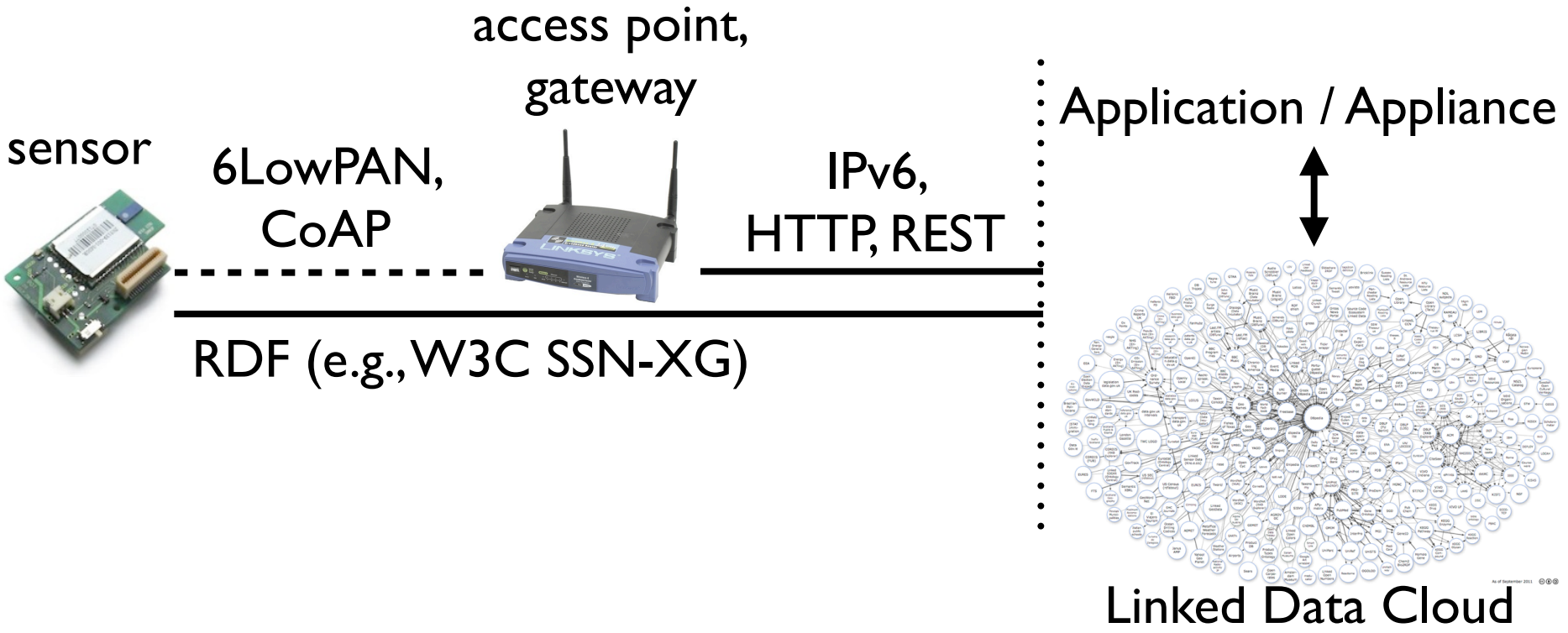

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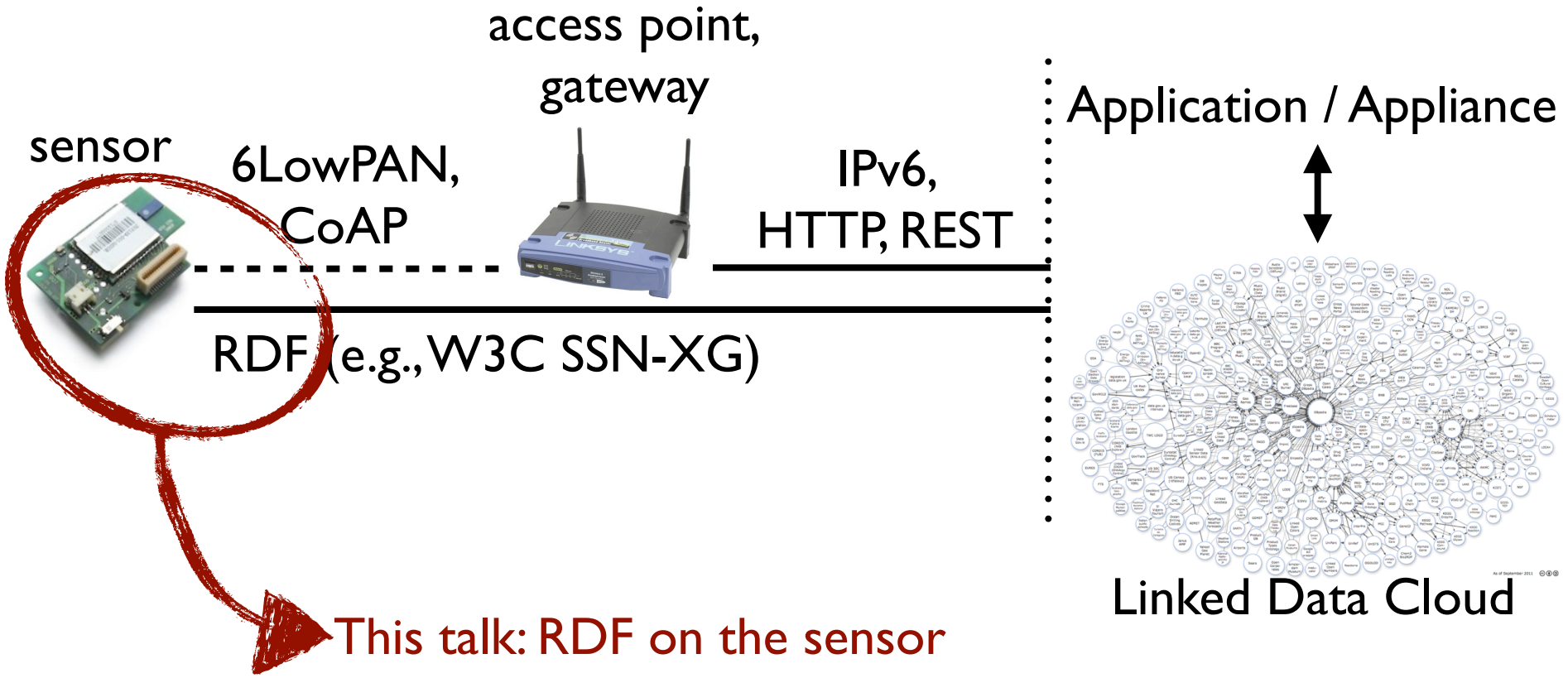

RDF represents facts as *subject–predicate–object* triples:

```
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>
```

Problem Space

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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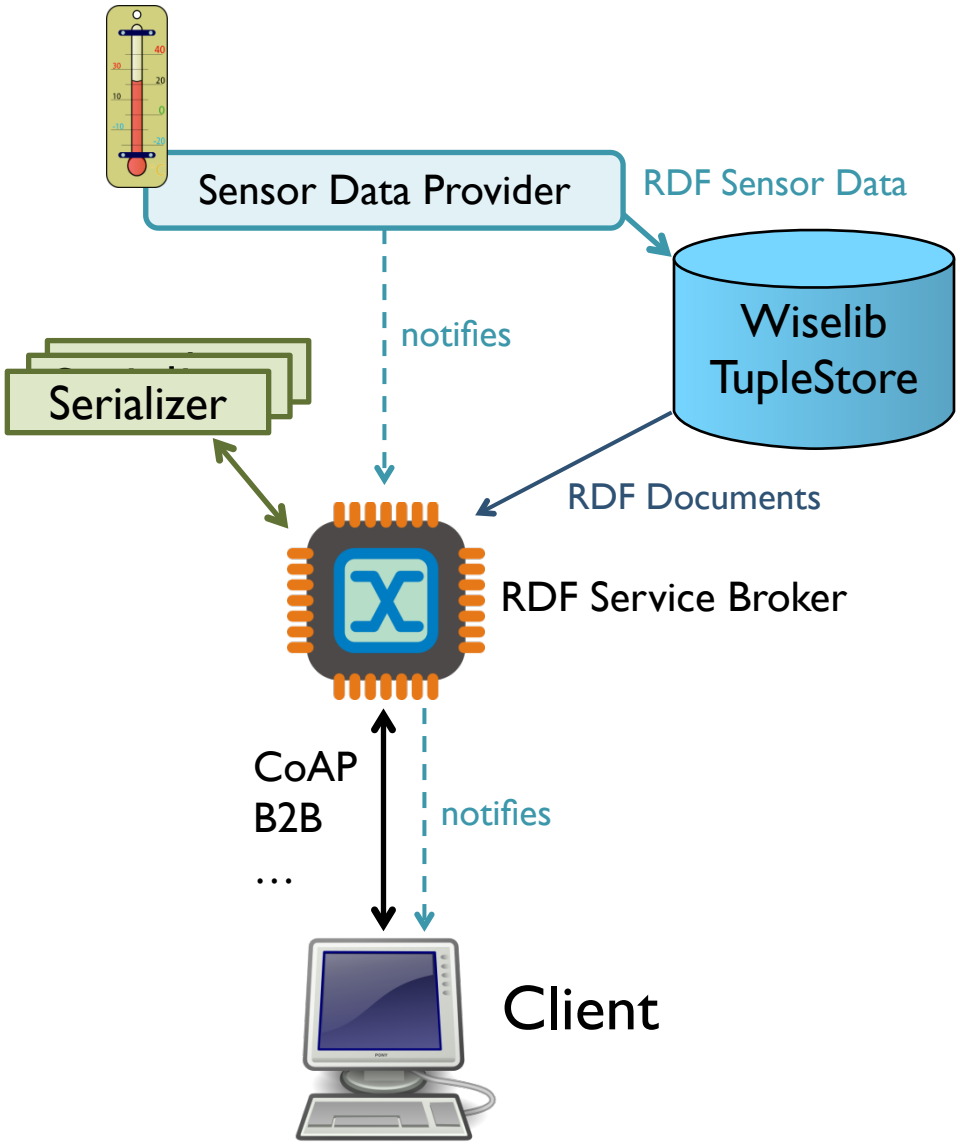
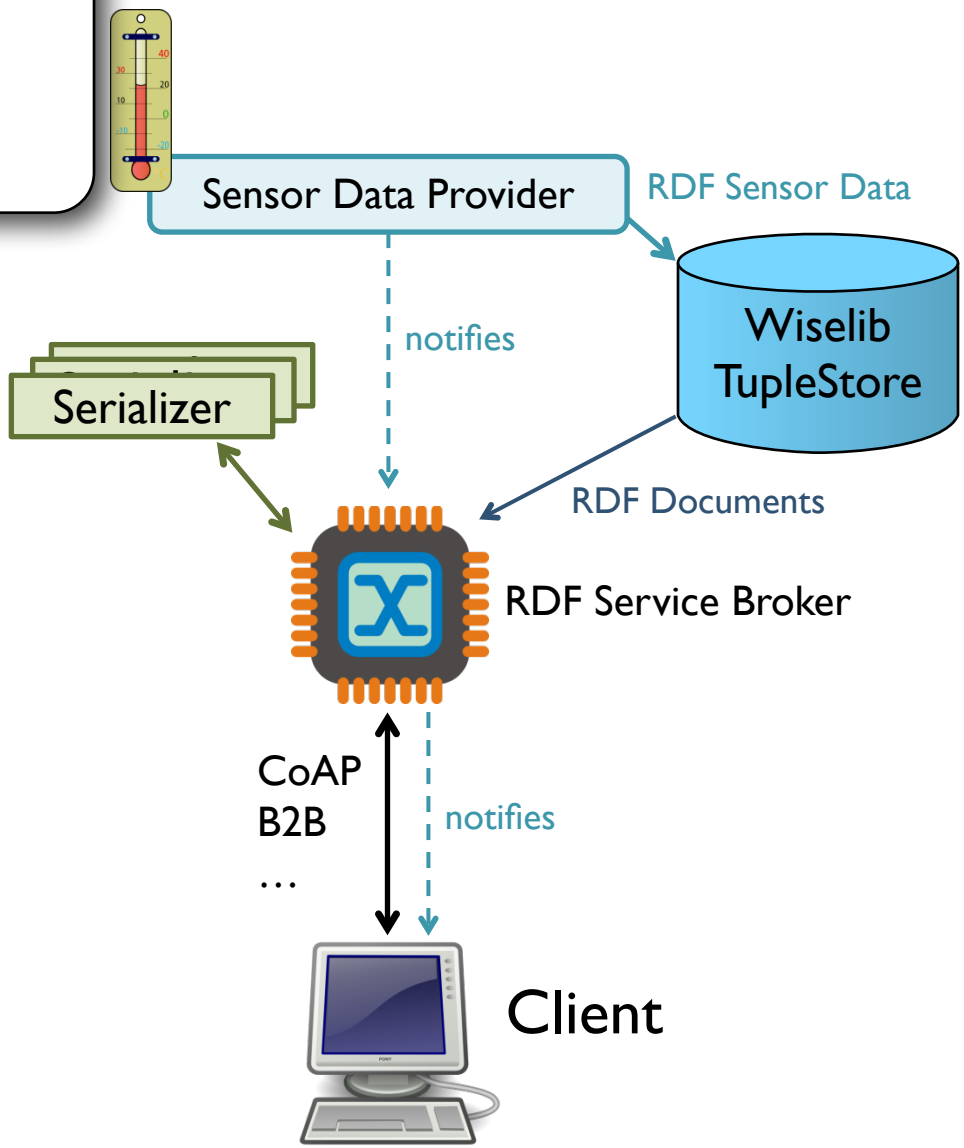
- **efficient** (communications)
- **efficient** (data storage)
- **platform-independent**

The Wiselib RDF Provider



The Wiselib RDF Provider

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



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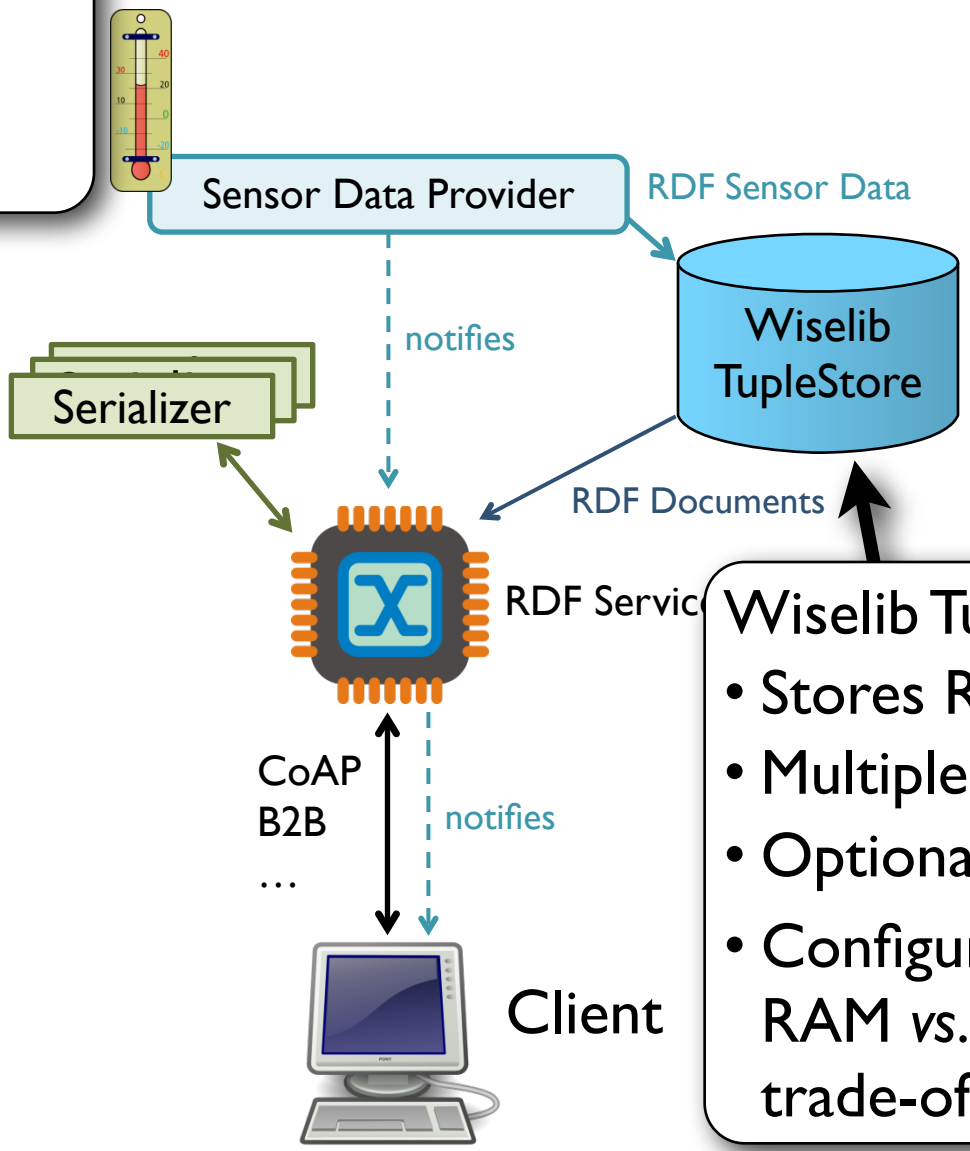

Wiselib TupleStore
- Stores RDF triples
- Multiple documents
- Optional compression
- Configurable code *vs.* RAM *vs.* energy trade-offs

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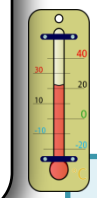

Sensor Data Provider
- Updates sensor data in the TS

Sensor Data Provider

RDF Sensor Data

Wiselib TupleStore

notifies

Serializer

RDF Documents

RDF Servic

CoAP
B2B
…

notifies

Client

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Client

Service Broker
- Provides document-level access
- Manages notifications

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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)

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Documents per device:

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Documents per sensor:

MINIMAL
(just the reading)

$\subseteq$

INTRINSIC
(+ basic info)

$\subseteq$

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“
...	

Broker Protocols II: Document-Level Interface

Document-Level Interface
- operates on RDF documents
- usually CoAP service requests from Internet

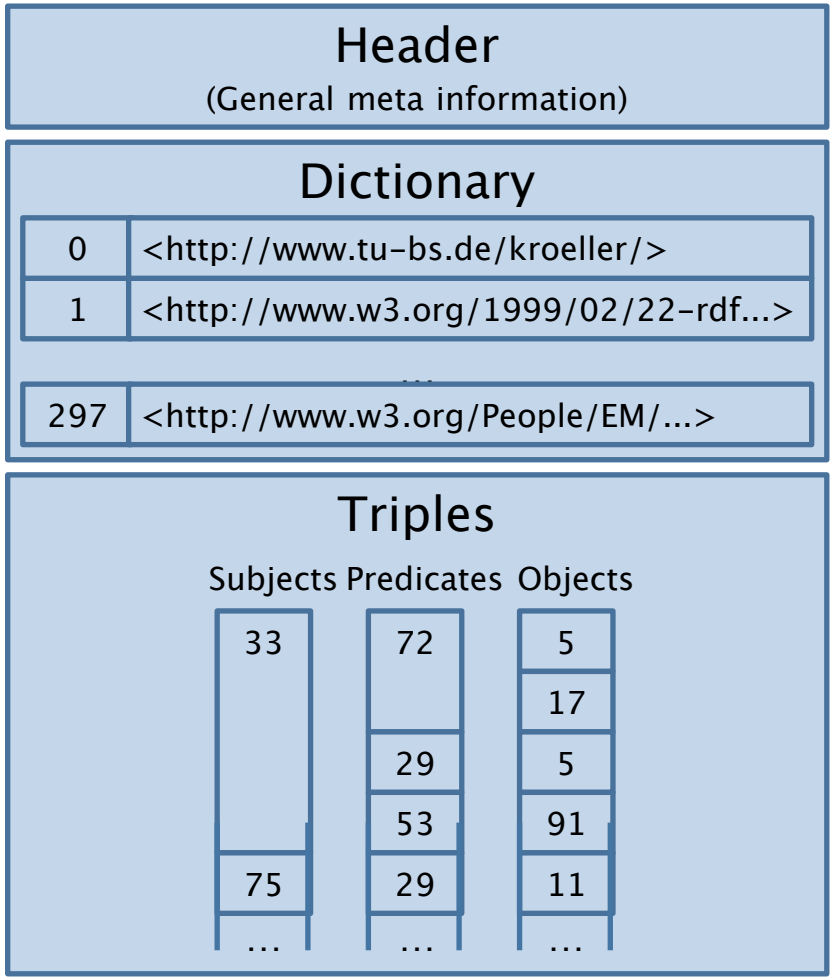
Operations:
- GET [*documentID*]
- POST [*documentIDs*] [*tuples*]
- DELETE [*documentID*] [*tuple*]

- 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
  $\hat{=}$ halving usable capacity

Streaming HDT

HDT [Fernandez et al. '10]

Header
(General meta information)

Dictionary

0	<http://www.tu-bs.de/kroeller/>
1	<http://www.w3.org/1999/02/22-rdf...>
...	
297	<http://www.w3.org/People/EM/...>

Triples

Subjects	Predicates	Objects
33	72	5
		17
	29	5
	53	91
75	29	11
...	...	...

"Streaming" HDT (SHDT)

Header
(General meta information)
ID bitwidth
ID space size

Stream

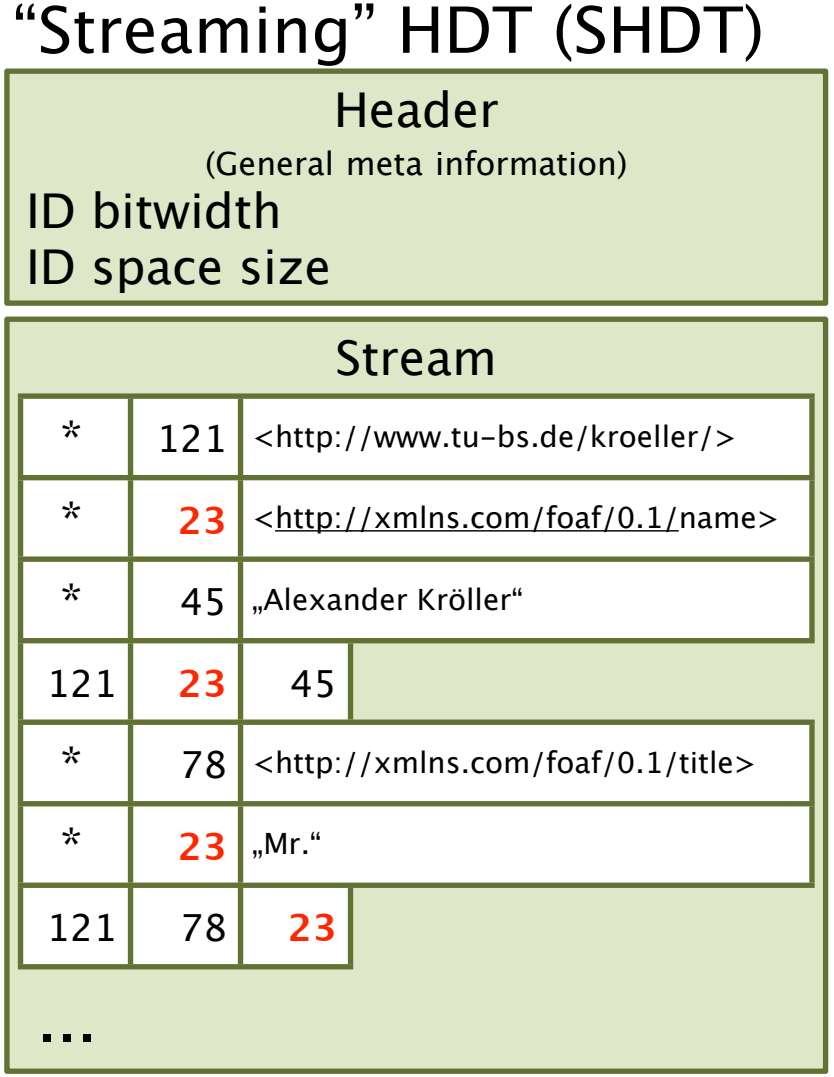
*	121	<http://www.tu-bs.de/kroeller/>
*	23	<http://xmlns.com/foaf/0.1/name>
*	45	„Alexander Kröller“
121	23	45
*	78	<http://xmlns.com/foaf/0.1/title>
*	23	„Mr.“
121	78	23

...

Streaming HDT

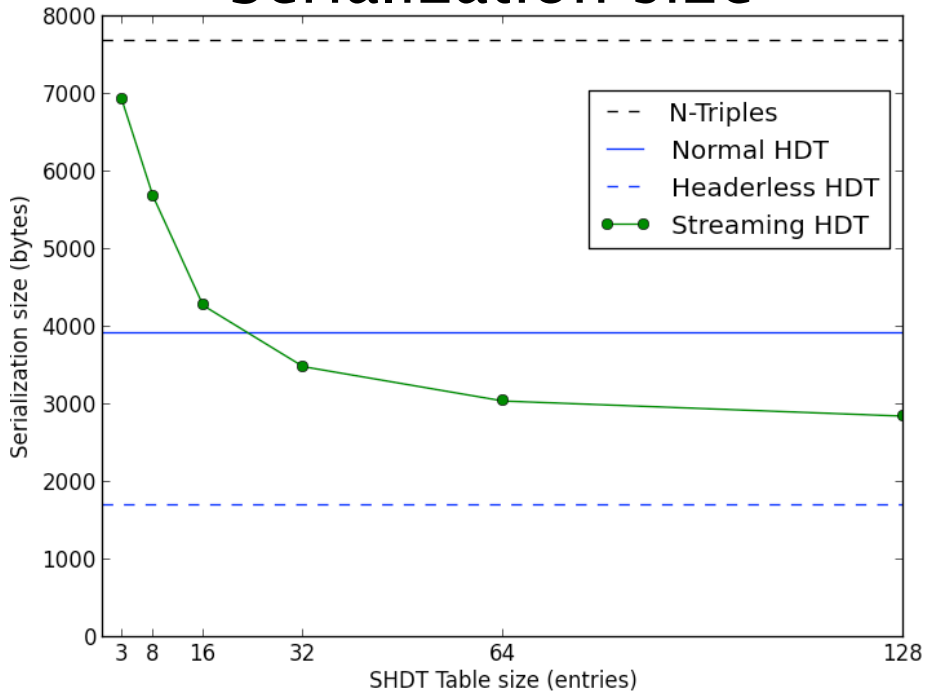
- Document usually transmitted from IoT device (constrained) to Internet host (unconstrained)
- SHDT exploits asymmetry

- *Sender* has freedom to decide ID space, mix dictionary/triples, re-use IDs.
- Allows for encoding on-the-fly, needs buffer for 1 packet plus hash table (any size)



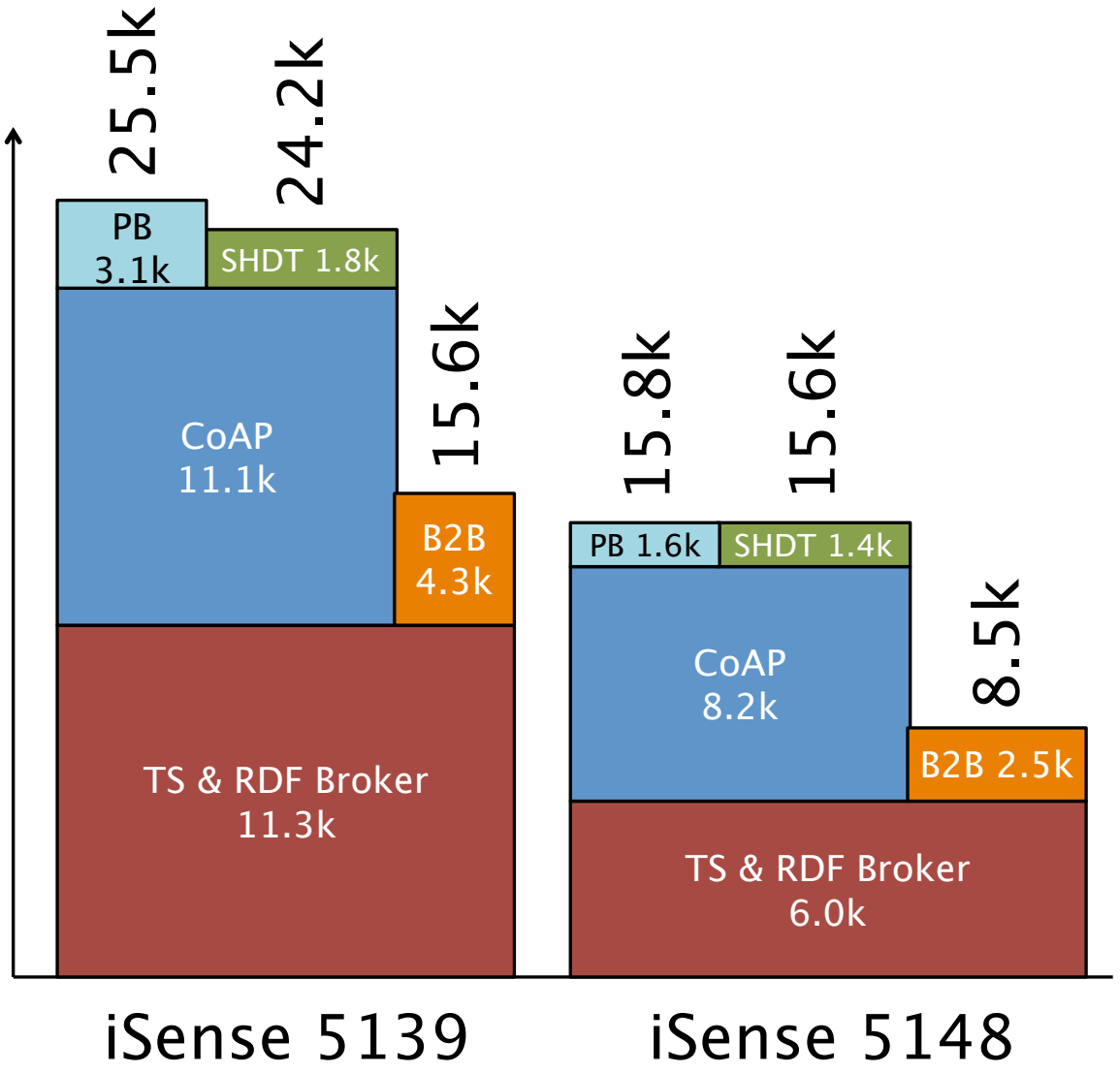
Evaluation – Streaming HDT

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.loa-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



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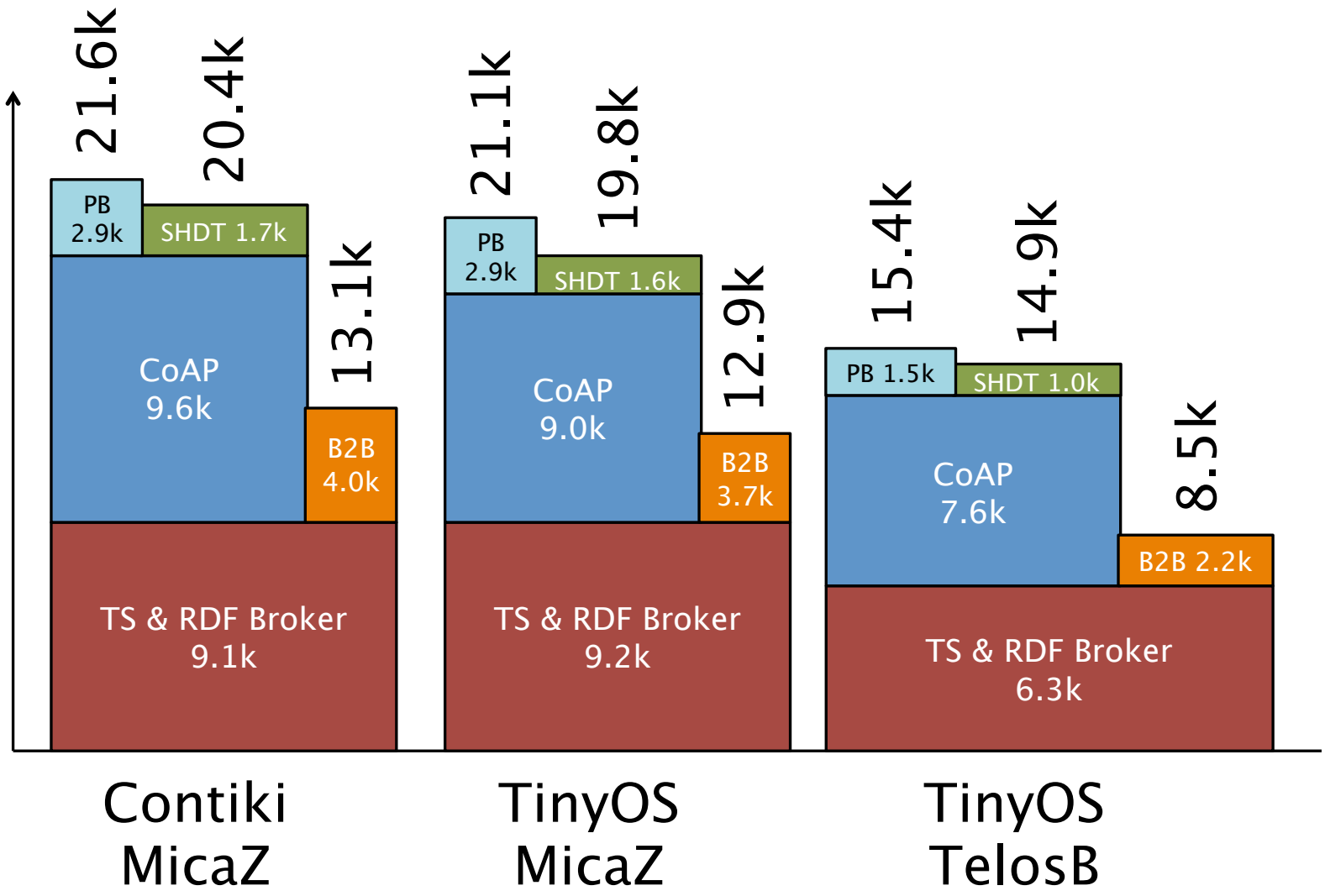
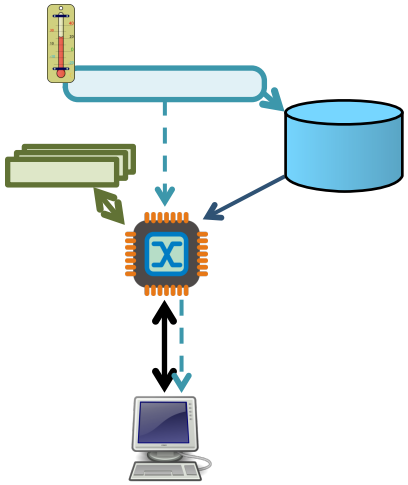


Contributions & Summary

"Node as RDF document"

NODE



- 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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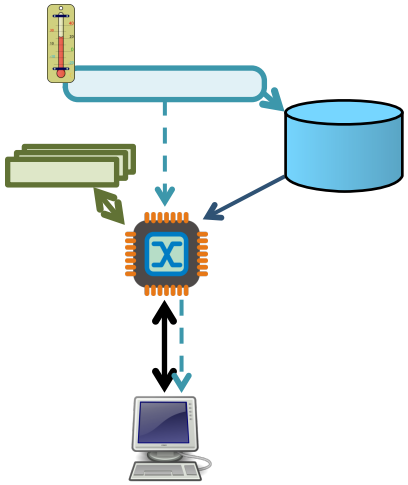

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The End. Thank You!