SEPSen: Semantic Event Processing at the Sensor Node for Energy Efficient Wireless Sensor Networks

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Low-power consumption environmental monitoring system

Wireless Sensor Networks (WSN's)
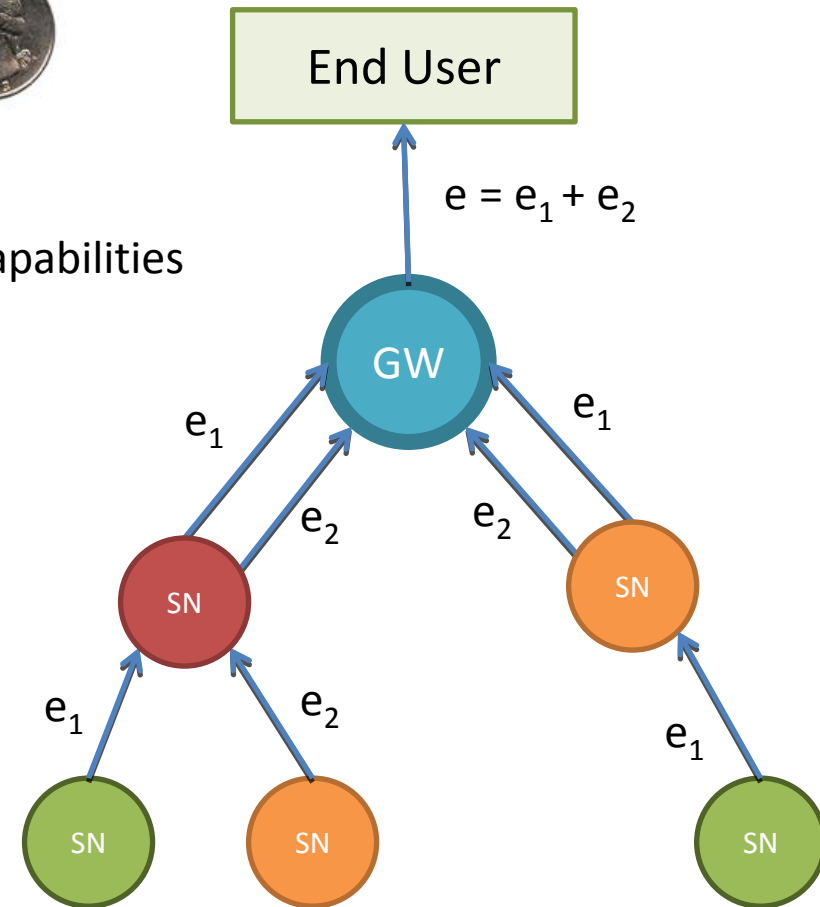
SN **Sensor Nodes**

- Large number (100-1000s)

- Sensing, processing & communication capabilities

- Collaborate with each other

GW **Gateway Nodes**

- More powerful

- Processes the data

- Relays data from network to end user

End User

$e = e_1 + e_2$

GW

e_1

e_2

e_2

e_1

SN

SN

e_1

e_2

e_1

SN

SN

SN

Remote areas

- Nodes are scattered
  (no way to go and change the
  battery or fix them)

- Heterogeneous nodes
  (may have similar or different
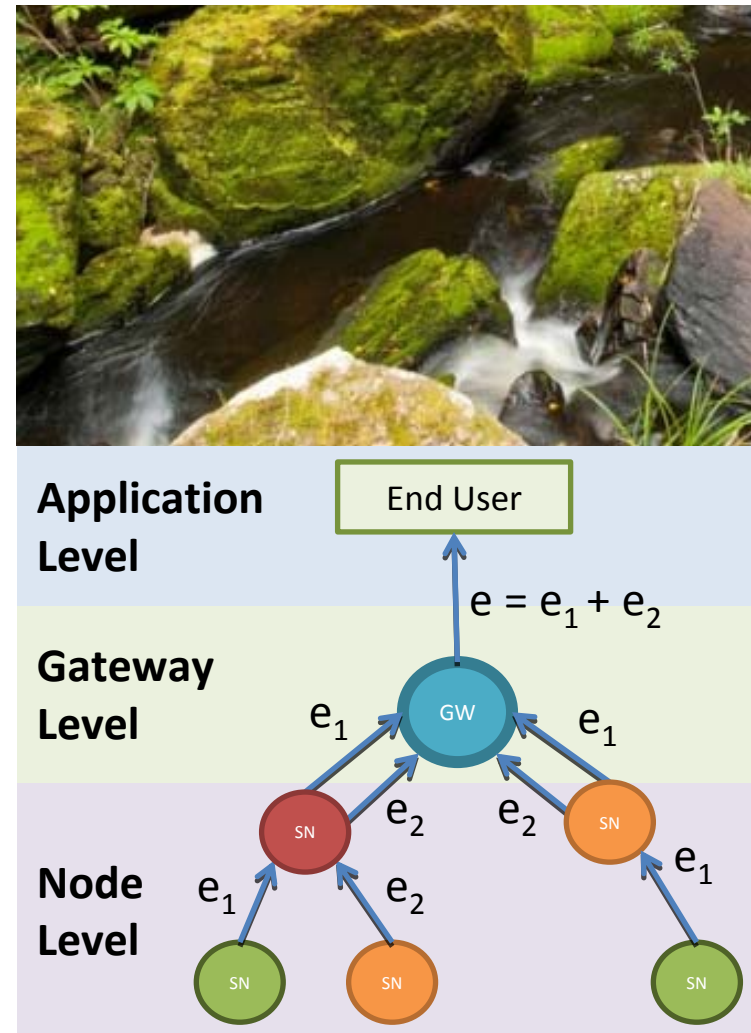 sensing capabilities)
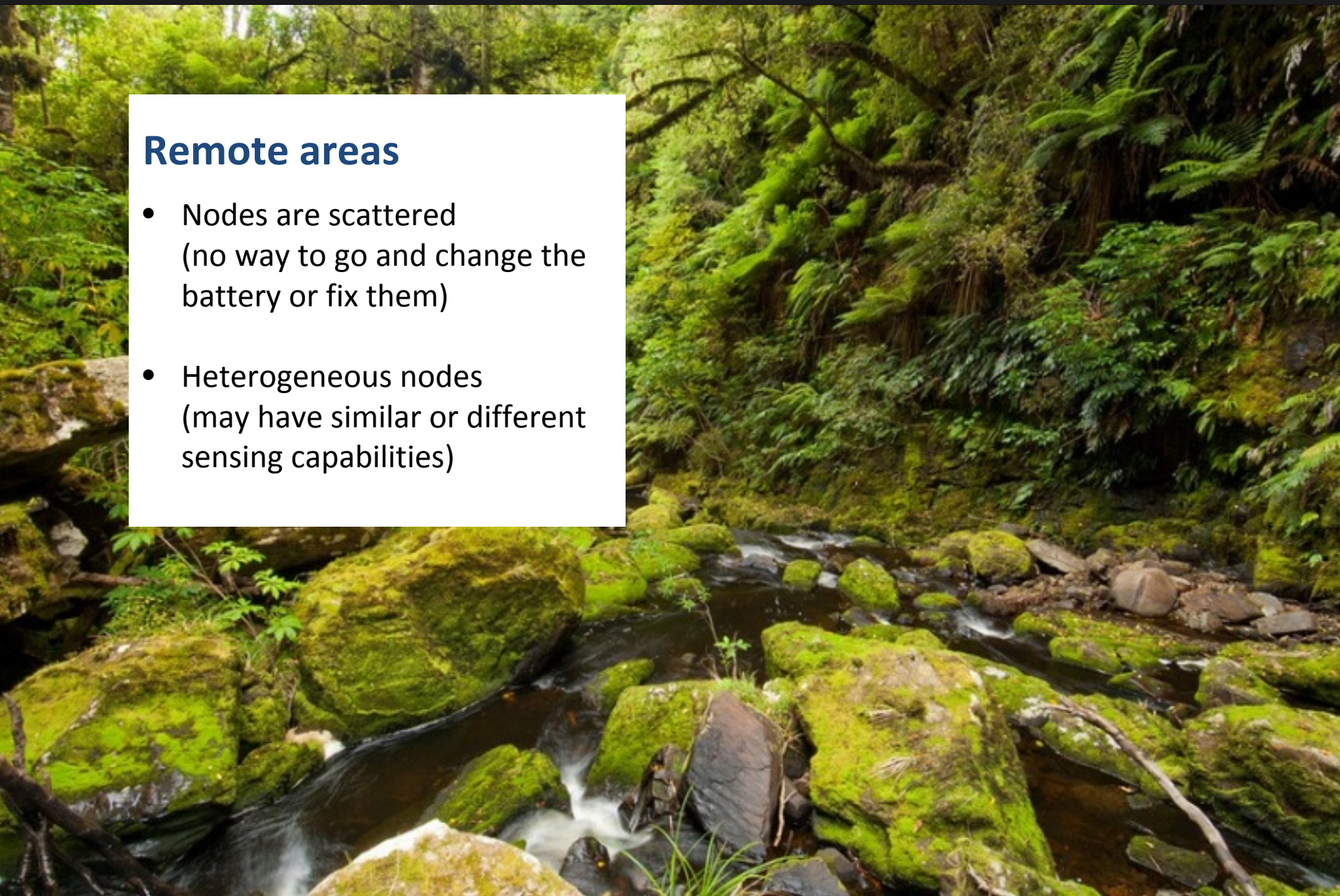
Data Integration in WSNs

User interested in higher level events

- Example: interest in the occurrence of a specific pollutant combination

- Needs data integration from heterogeneous nodes

Typical approach…

- Sensor nodes used for capturing only

- Processing at upper levels (GWs)
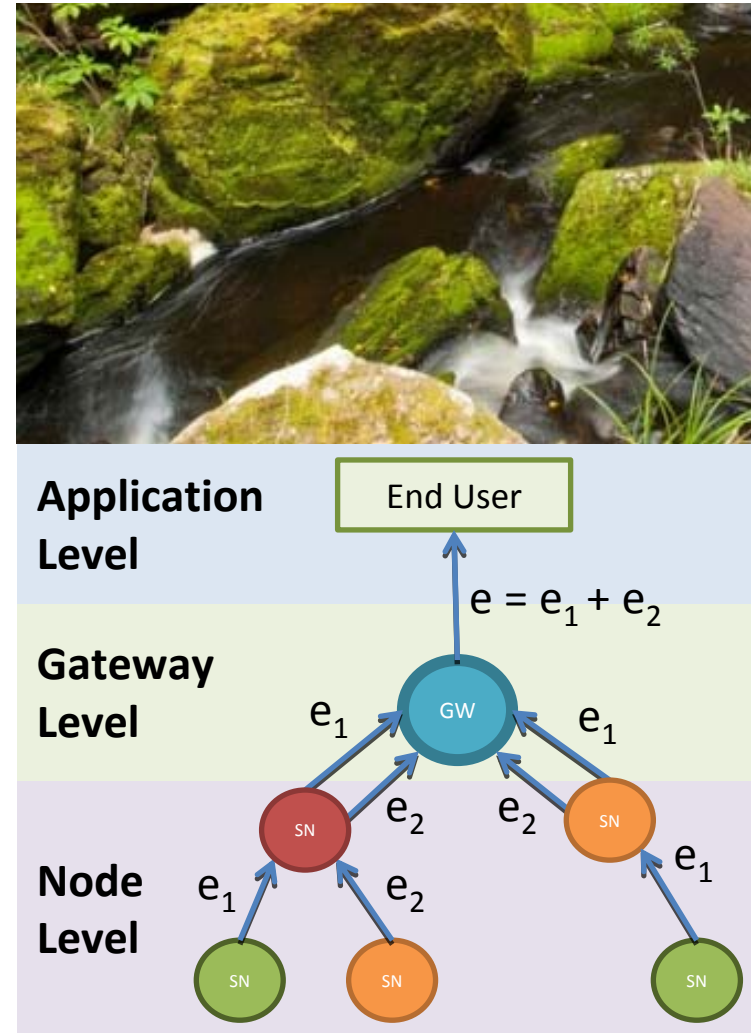
- Wastes energy at the sensor nodes

Application Level   End User

$e = e_1 + e_2$

Gateway Level e_1 GW e_1

Node Level e_1 SN e_2 e_2 SN e_1

e_1 SN e_2 SN   SN

Challenges in WSN's

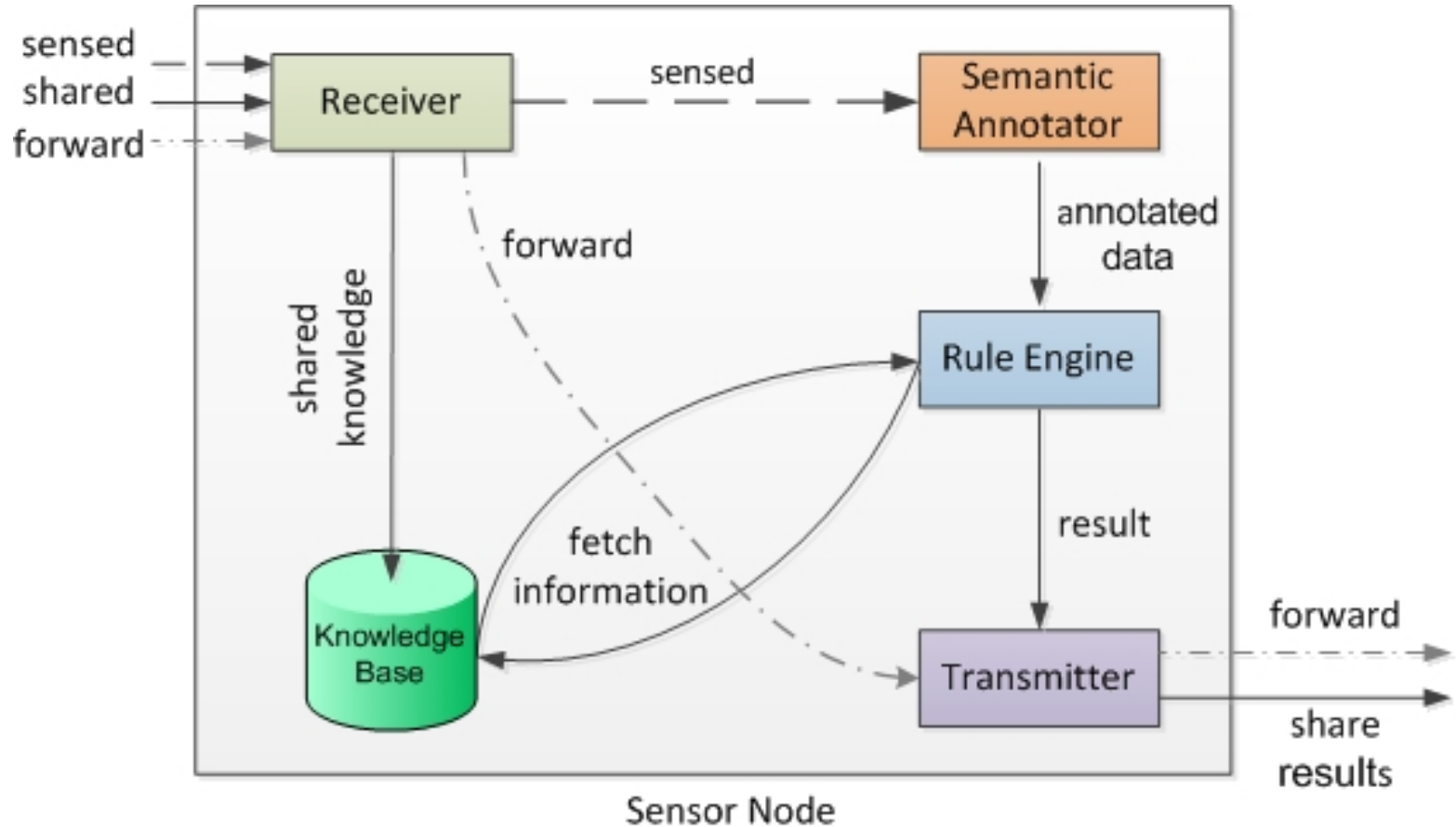| Solution	Existing work predominantly...
In-network Data Processing	**Homogeneous sensor nodes**
Ontologies	**Processing at the gateway nodes**
Context-Awareness	**Limited to infrastructure context**

Proposed Solution

SEPSen: Processes data locally at the sensor node level

At sensor nodes level:

- semantically annotate sensed data

- collaborate with surrounding sensor nodes

- apply rules on the gathered knowledge.

Application Level — End User

$e = e_1 + e_2$

Gateway Level — e_1 GW e_1

e_2 e_2 SN

SN

Node Level — e_1 e_2 e_1

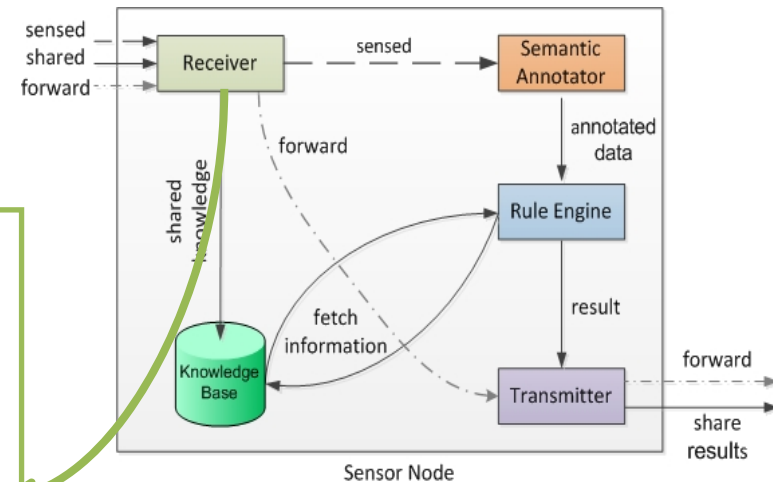SN   SN   SN

Sensor Node Architecture

Overview of SEPSen:
Receiver

Distinguishes three types
of incoming events:

- Sensed event
- Shared event (for composition)
- Forwarded event (communication)

Overview of SEPSen:
Semantic Annotator

Ontology fragment available at WaterpH sensor node

@prefix ont:<http://www.co-ode.org/ontologies/ont.owl#>
@prefix owl:<http://www.w3.org/2002/07/owl#>
@prefix rdfs:<http://www.w3.org/2000/01/rdf-schema#>

ont:MeasurementSite rdf:type owl:Class;

ont:ObservedProperty rdf:type owl:Class;

ont:Measurement rdf:type owl:Class;

ont:WaterMeasurement rdf:type owl:Class;
     rdfs:subClassOf ont:Measurement.

ont:WaterProperty rdf:type owl:Class;
     rdfs:subClassOf ont:ObservedProperty.

ont:WaterPH rdf:type owl:Class;
     rdfs:subClassOf ont:WaterProperty.

ont:hasProperty rdf:type owl:ObjectProperty;
     rdfs:domain ont:MeasurementSite;
     rdfs:range ont:WaterProperty.

ont:hasMeasurement rdf:type owl:ObjectProperty;
     rdfs:domain ont:MeasurementSite;
     rdfs:range ont:WaterMeasurement.

ont:hasValue rdf:type owl:DatatypeProperty;
     rdfs:domain ont:WaterProperty;
     rdfs:range xsd:double.
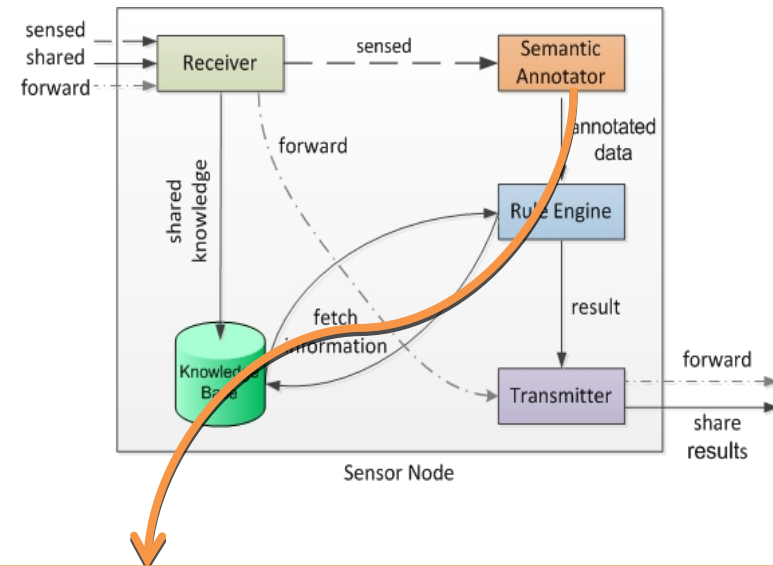
- Relevant ontology fragments in each node

- Events are semantically annotated

- Main ontology at GW for overall application.

- Current status: Manual ontology infusion
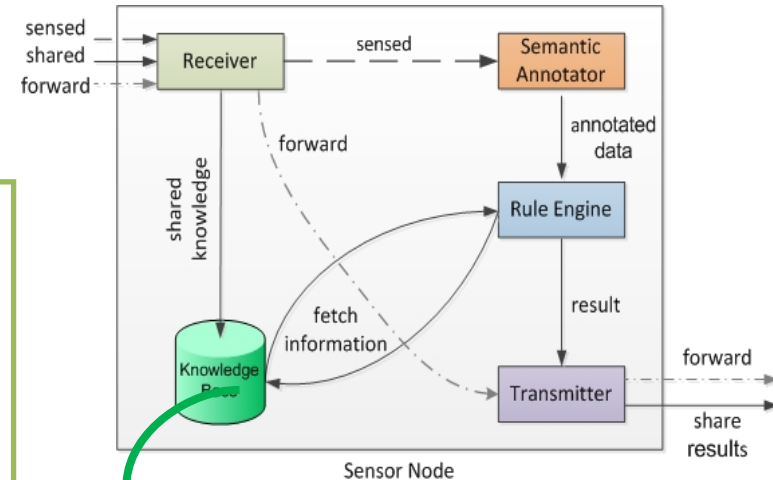
Overview of SEPSen:
Knowledge Base

The Knowledge Base of a sensor node contains:

Facts base:
- event data recorded by sensors
- changing at runtime

Rules base:
- semantic rules (IF-THEN)
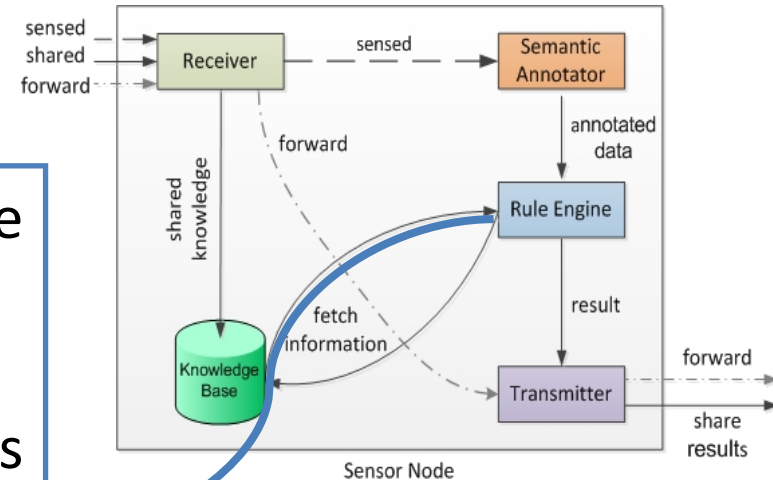- may be updated over time

Overview of SEPSen:
Rule Engine

Rule Engine based on the RETE algorithm [3].

Pattern network of nodes that encodes the condition parts (IF-parts) of the rules.
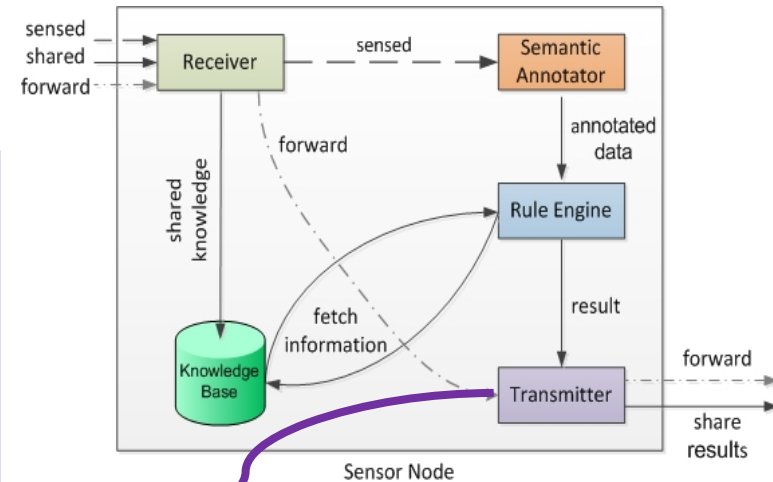
Triggered actions:
- Discard (non-matching)
- Share (partial match)
- Forward (complete match)

Overview of SEPSen:
Transmitter

- Transmission to gateway and other relevant sensor nodes.

- Designed to use the context information (e.g., node energy levels) of the sensor network for routing decisions.

- Current status: context information not utilised yet

Evaluation: Simulation

Setup:

- Implementation of SEPSen and water pollutant application
- Simulations using PowerTOSSIM [16].
- Energy model based on Mica2 sensor nodes.
- Average over 60 seconds, one message per second.
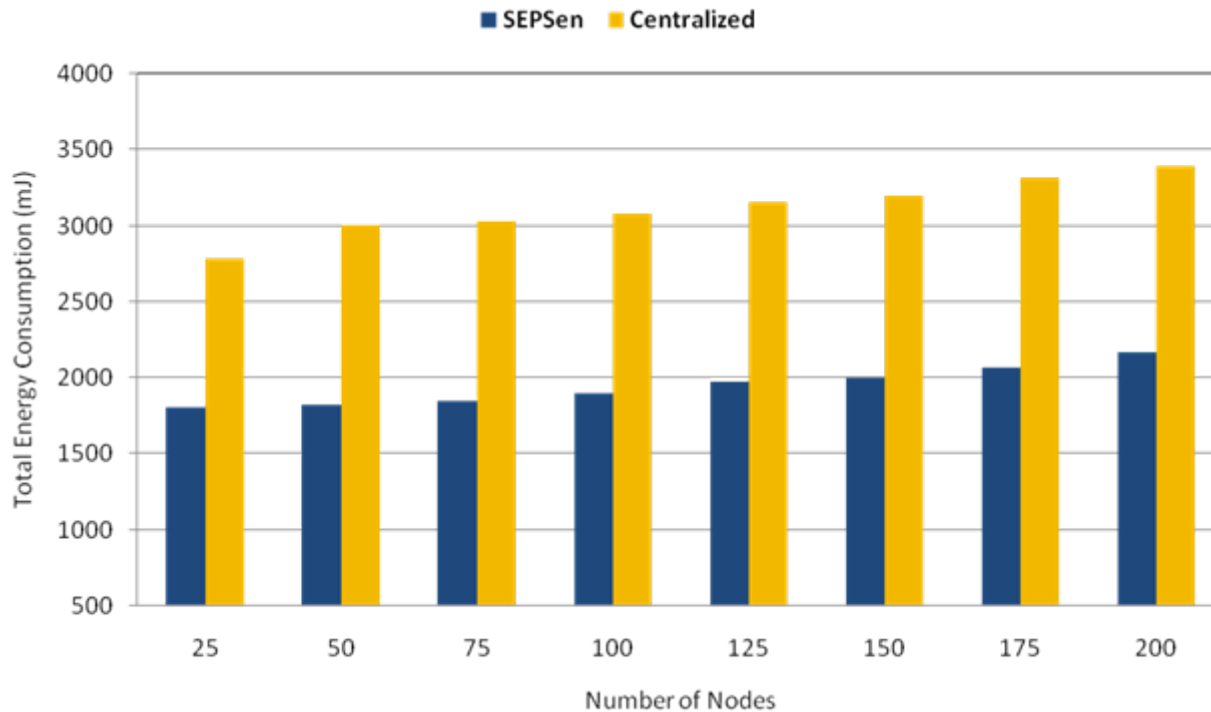
Evaluation Goal:

- Performance comparison between semantic in-network processing and centralized approach (processing at gateway nodes)   [cf. cost model (DEBS'11)]
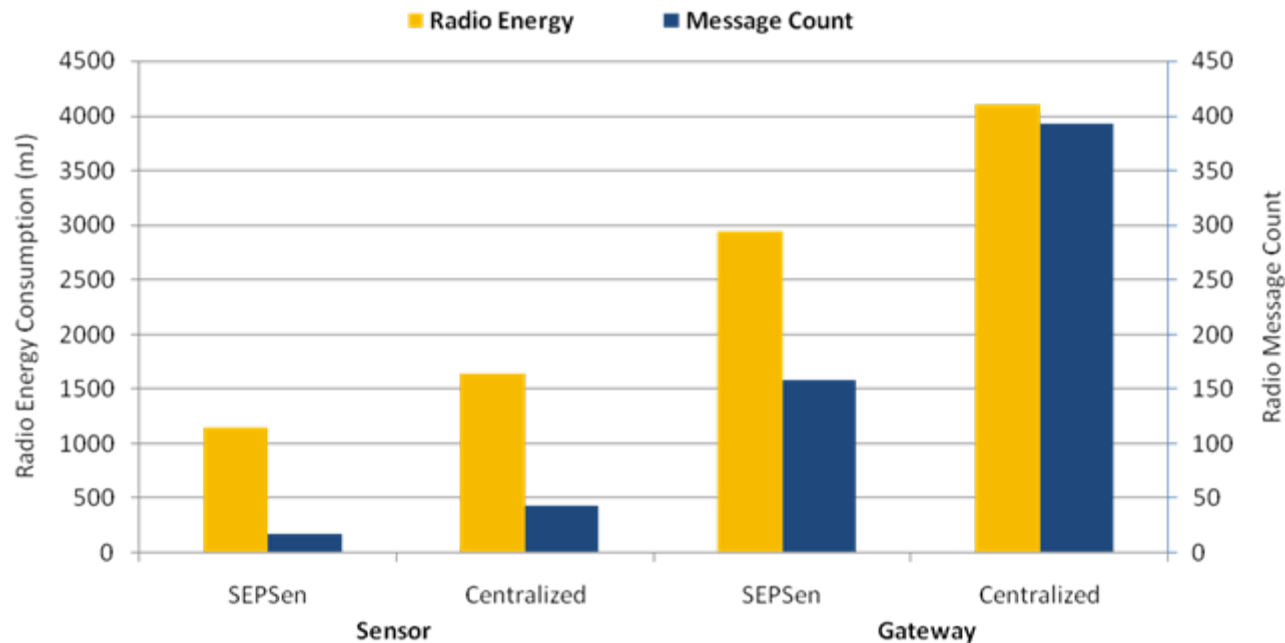
Evaluation

Test-1: Total Energy Consumption

Energy conservation from *13% for 25 nodes* to *16% for 200 nodes.*

Evaluation

Test-2: Radio Energy & Radio Message Counts

Nodes in the centralized architecture sent
nearly *three times as many messages* as in SEPSen.

Conclusion

- Unpredictable, heterogeneous WSN "in the wild".
- Processing at gateway nodes reduces WSN lifetime.

SEPSen

- uses processing capabilities of sensor nodes (in-network)
- aims for energy conservation in WSNs.
- simulation results promising

Next steps:
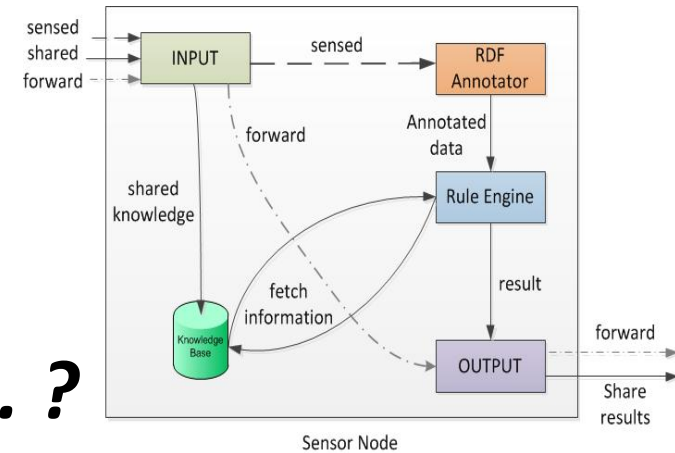
- automate Ontology infusion
- evaluate variation of complex events
- context-awareness at the sensor node level

Thank you.
Questions ... ?

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The MICA mote uses an Atmel ATmega 128L processor running at 4 megahertz. The 128L is an 8-bit microcontroller that has 128 kilobytes of onboard flash memory to store the mote's program. This CPU is about as powerful as the 8088 CPU found in the original IBM PC (circa 1982).

This low power consumption allows a MICA mote to run for more than a year with two AA batteries.

MICA motes come with 512 kilobytes of flash memory to hold data. They also have a 10-bit A/D converter so that sensor data can be digitized. Sensors available include temperature, acceleration, light, sound and magnetic.

The final component of a MICA mote is the radio. It has a range of several hundred feet and can transmit approximately 40,000 bits per second. When it is off, the radio consumes less than one microamp. When receiving data, it consumes 10 milliamps. When transmitting, it consumes 25 milliamps. Conserving radio power is key to long battery life.

Software on MICA motes is built on an operating system called TinyOS. TinyOS is helpful because it deals with the radio and power management systems for you and makes it much easier to write software for the mote.