

Towards Energy Efficient XPath Evaluation in Wireless Sensor Networks

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Outline

Motivation

XML in Wireless Sensor Networks

Basics and Environmental Work

Challenges

Contribution

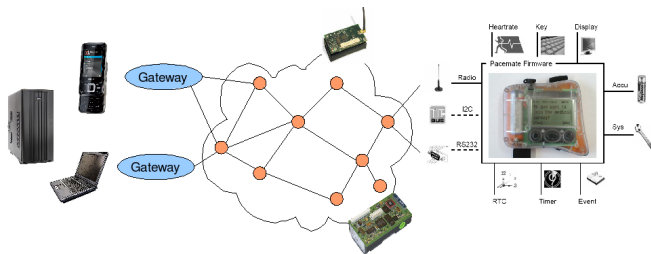
XPath Evaluation

Experiments and Results

Test Environment and Evaluation Standard

XML Programming Environment

Communication in Wireless Sensor Networks

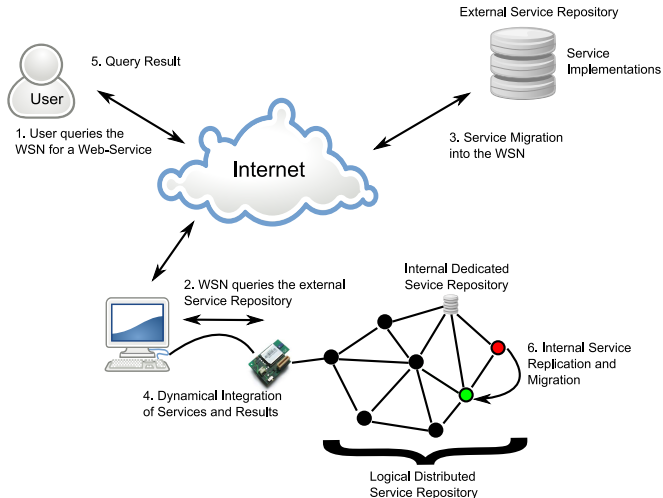


- Exchangeability problem
- Complex programming requires expert skills
- Handling communication formats during programming
 - is often even more complex
 - can cause programming errors
 - may result into unstable programs
 - may result into extra deployment costs

XML in Sensor Networks

- XML...
 - is a highly exchangeable data format
 - encourages using different sensor node products (Application Layer, GSN approach)
 - simplifies connecting to sensor networks (e.g. WWW <-> sensor network)
 - is supported by standardized query languages (e.g. XQuery, XSLT)
 - is self-descriptive and supports heterogeneous data in sensor networks
 - is the key feature towards Service-Oriented Sensor Networks (**AESOP's TALE**)

AESOP's TALE Project Overview



Limitations & Goals

- XML is verbose
 - Sensor node memory and energy consumption is still a bottleneck
 - Typical sensor node platform 32-64kB RAM and 128-256kB Flash
 - \implies compress XML but let it be dynamically accessible (**XOBE Template Objects Compression** / WICON 2008)
- Complex sensor node programming
 - Transparent integration of XML in the programming language (**XOBE** / INSS 2008)
 - Support Service-Oriented Sensor Networks
- Open Issue: Query Processing on compressed XML

Summary of Design Decisions

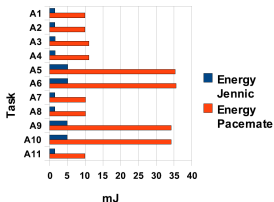
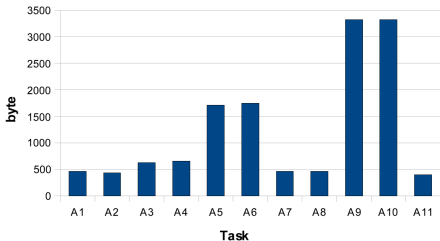
- How to access XML data for evaluation?
 - direct access vs. navigation/reevaluation
- How to evaluate XPath queries efficiently?
 - XML compression includes serialized SAX events
 - evaluation is done by a mealy machine simulation
- How to store XPath results?
 - crucial for memory efficiency
 - runtime vs. memory demand
 - example: ancestor axes
 - adaptable marker structure
- How to optimize the XPath evaluation?
 - result delivery, template caching, heterogenous aggregation

Evaluation Environment

- Sensor Node Platform
 - iSense core modules (Jennic 32bit RISC) , Pacemates (Philips LPC 2196)
 - available RAM 96kB (15kB Heap and 81kB Program)
- Evaluation Test Cases
 - Status Delivery, XPathmark Functional Test



Status Delivery XML Memory Usage



- Tasks A5, A6, A9, A10 include ancestor axis evaluation
- Tasks A3, A4 include descendant axis evaluation

General Program Memory Demand

Program Functionality	Memory Demand in bytes
XML Framework	7744
XPath Engine	18734
XPathMark Program	704
Debug Routines	668

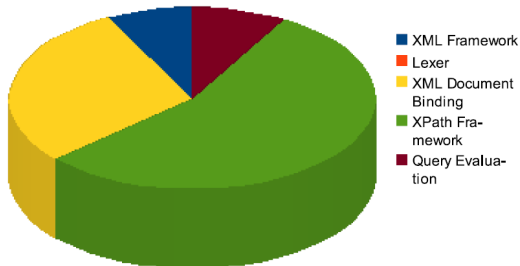


Figure: Memory Consumption Query Task A1 //L/* XPathMark

Summary

- XML integration in sensor network programming
- XML compression
- Native XPath Evaluation on sensor nodes is possible
- Outlook
 - Continuous Query Support
 - SOAP Support
 - Optimized Memory Management

Thank you!

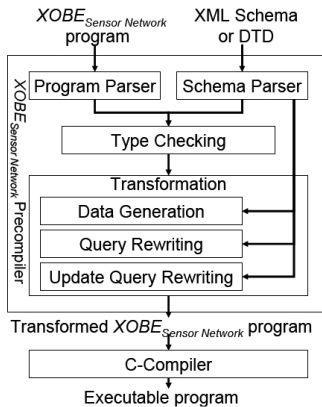
Any questions?

XML OBjEcts Sensor Network Programming

XOBE Sensor Networks integrates into existing Sensor Node Programming Languages (e.g. Embedded C)

It provides...

- Transparency
- Stability
- Efficiency

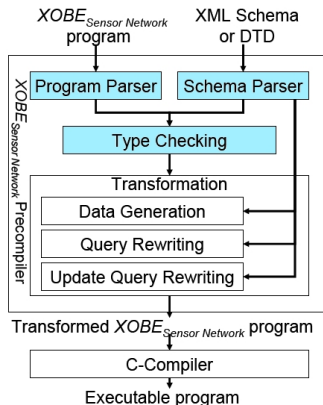


XML OBjEcts Sensor Network Programming

Transparency

- Using XML directly within the programming language

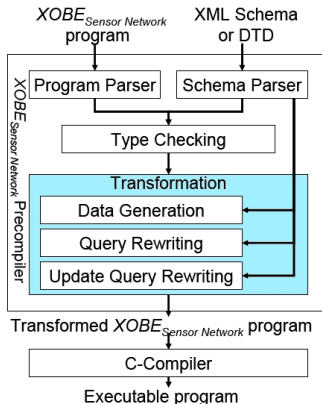
```
xml<status> var;  
while(true) {  
var = <status sensorid='1'>  
  <temp>  
    {readTempSens()}  
  </temp>  
</status>;  
send(var); }
```



XML OBjEcts Sensor Network Programming

Transformation Requirements

- Eliminate the XML overhead
- Represent XML in target language
- Allow dynamic accessibility
- Allow query processing
- Provide automatic XML transformation into compressed format



Transformation Tasks

- 1. Transform / Compress XML assignments (and XML queries) during compiletime

```
sensor = <btsysinfo>  
    <timestamp>{time}</timestamp>  
    <bat>{battery}</bat>  
    {sensor}  
</btsysinfo>;
```

- 2. Verify / Update transformation during runtime (e.g. important for DDL)

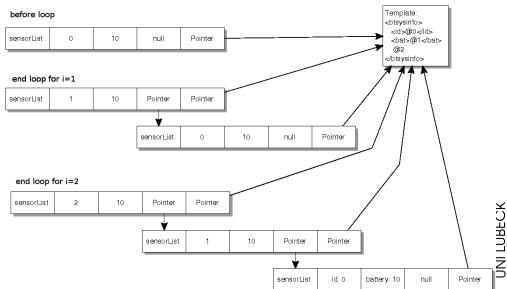
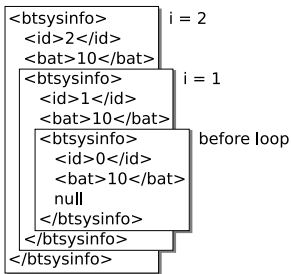
XML Templates: From XML fragments to data binding

- Split up XML fragments into dynamic and static parts
- Define static parts (TEMPLATE) by finding repeating structures
- Compress static parts
- Manage dynamic parts separately and link them to static parts
- Verify and update templates during runtime

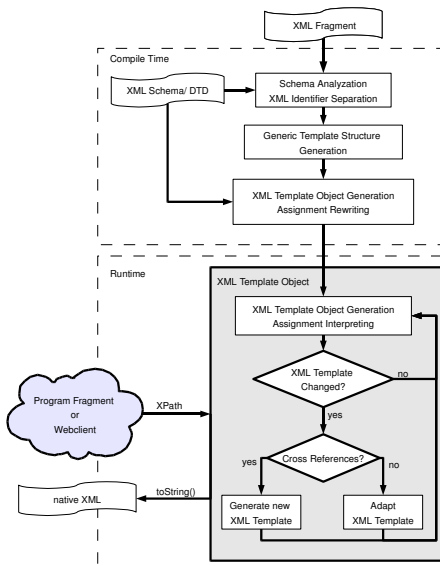
```
<btsysinfo>  
  <timestamp>@1</timestamp>  
  <bat>@2</bat>  
  @3  
</btsysinfo>
```

XML Template Transformation Example

```
for (int i=1; i <=n; i++) {  
    sensor = <btsysinfo>  
        <timestamp>{getTime()}</timestamp>  
        <bat>{getBattery()}</bat>  
        {sensor}  
    </btsysinfo>;  
}
```

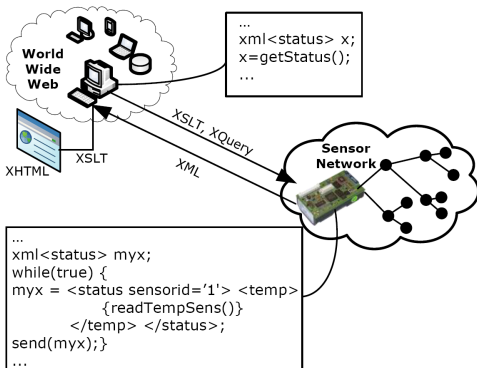


XML to XML Template Object Transformation



Further Optimizations

- Areas of optimization
 - Element / Attribute Name Management
 - Template Storage
 - Query to Template Translation



Backup

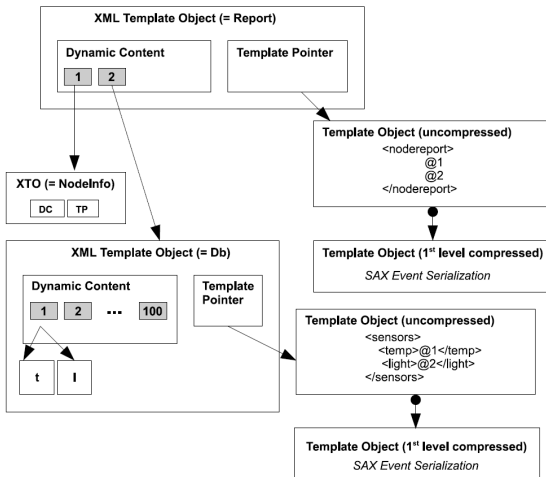
Listing 1: Xobe Example Code 1

```
...
xml<nodereport> Report;
xml<sensors> Db[] = new xml<sensors >[100];
xml<nodeinfo> NodeInfo;
NodeInfo = <nodeinfo id='1' rev='0.1'
            battery={remainingEnergy()}/>;

...
// Repeated Sensory Task
// t and l are the current sensor values
// i is the next insertion place in a ring buffer
Db[i] = <sensors>
        <temp>{t}</temp>
        <light>{l}</light>
    <sensors>;

...
// Task in case of query for full report
Report = <nodereport>
        {NodeInfo}
        {XMLUnfold(Db,100)}
    <nodereport>;
```

Backup

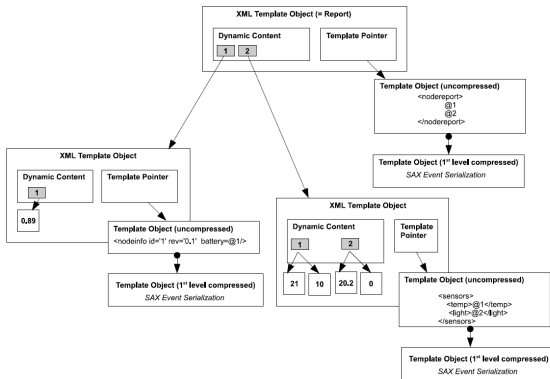


Backup

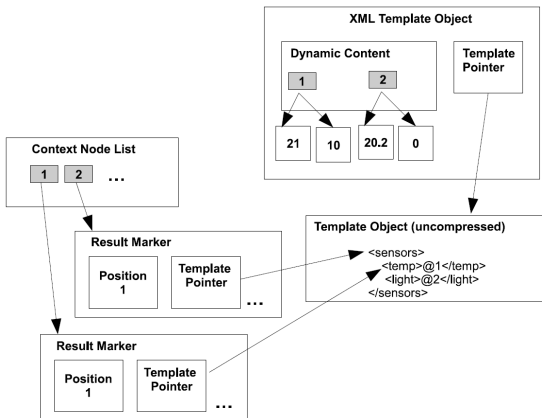
Listing 2: Xobe Example Code 2

```
...
NodeInfo = <nodeinfo id='1' rev='0.1'
  • battery={remainingEnergy()}/>;
XVar = <data>
  {NodeInfo}
  <sensors>
    <temp>{t}</temp>
    <light>{l}</light>
  </sensors>
  • <previous>{XVar}</previous>
</data>;
...
```

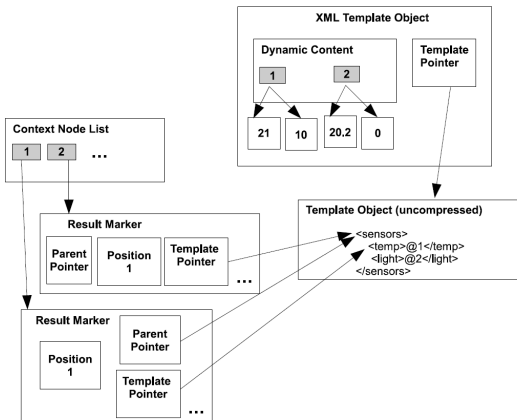
Backup



Backup



Backup



Backup

