innovations
for high
performance
microelectronics

Tool-supported Composition of Software Modules for Safe and Secure Wireless Sensor Networks

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Outline

- Introduction IHP & Related Projects
- Motivation
- Configuration Tool Approach
- Module Selection
- Security Assessment
- Conclusion

New Institute & Cleanroom

IHP in a Nutshell

The Institute

- Founded in 1991; successor institution to the former institute of the East German Academy with extensive experience in silicon microelectronics
- 200 employees from 16 countries
- Member of the Gottfried Wilhelm Leibniz Society (WGL)

Mission

- Strengthen the competitive position of the German and European microelectronic and communication research
- Act as an innovation center, leading research results towards prototypes
- Enhance the attractiveness of the region as location for high technology

Facilities

- Complete innovation chain from materials to systems, including class-1 c.leanroom, 0.13 µm capable pilotline

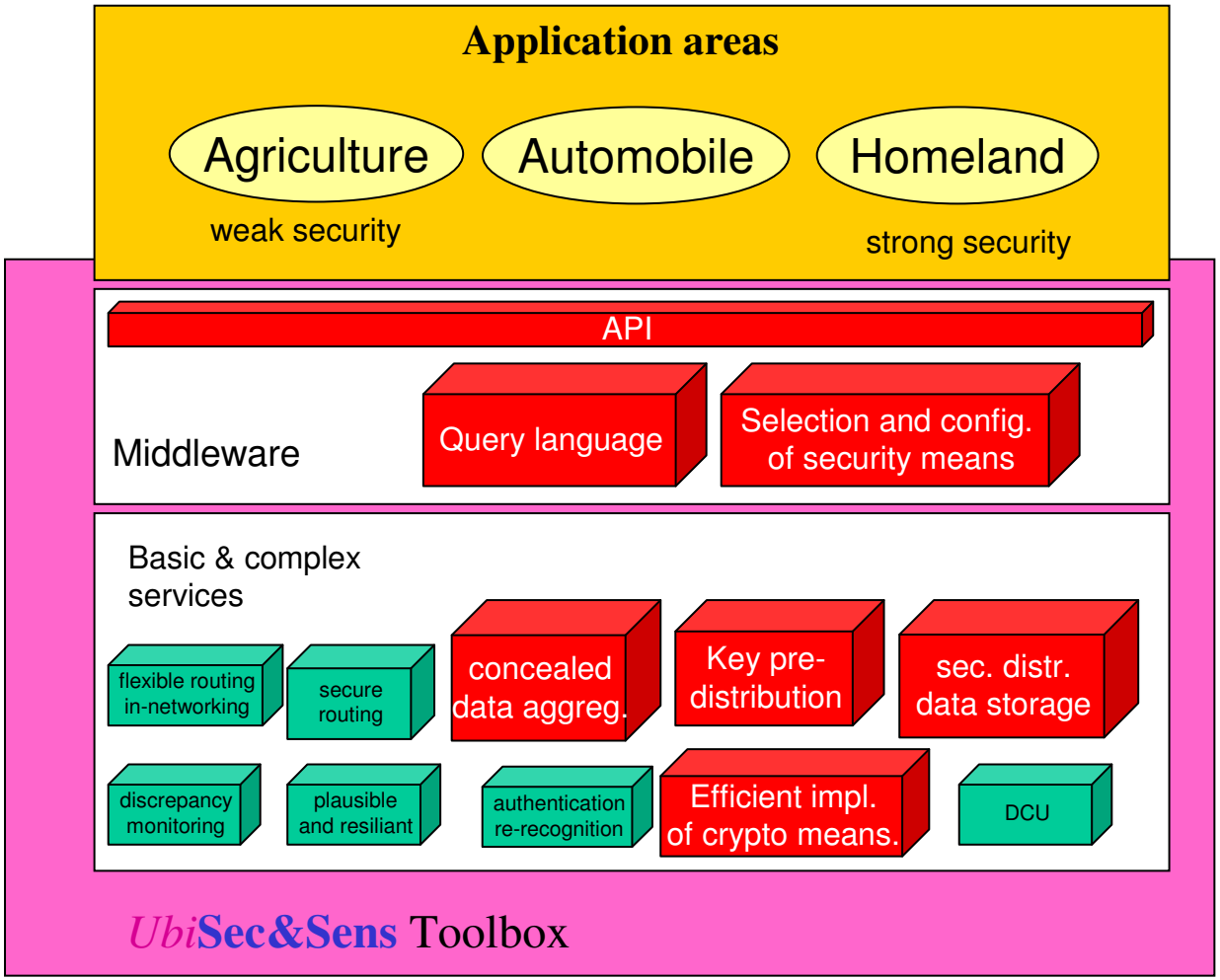
Competencies

- Systems for wireless communication
- RF circuit design
- Extension of silicon CMOS technologies
- Materials for microelectronic technology

Strategy

- Create value through innovation
- Focus on solutions for wireless & broadband communications
- Development of forward-looking technologies and system-level prototypes
- Strategic partnerships

UbiSec&Sens Project (2006-2008) Overview



UbiSec&Sens Vineyard Scenario (2008)

The setting

- Commercially run vineyard "Weingut Georg Naegele" in Neustadt, Germany
- Deployment in operational part of the vineyard, no special arrangements
- Requirements collected together with the proprietors

Key requirements

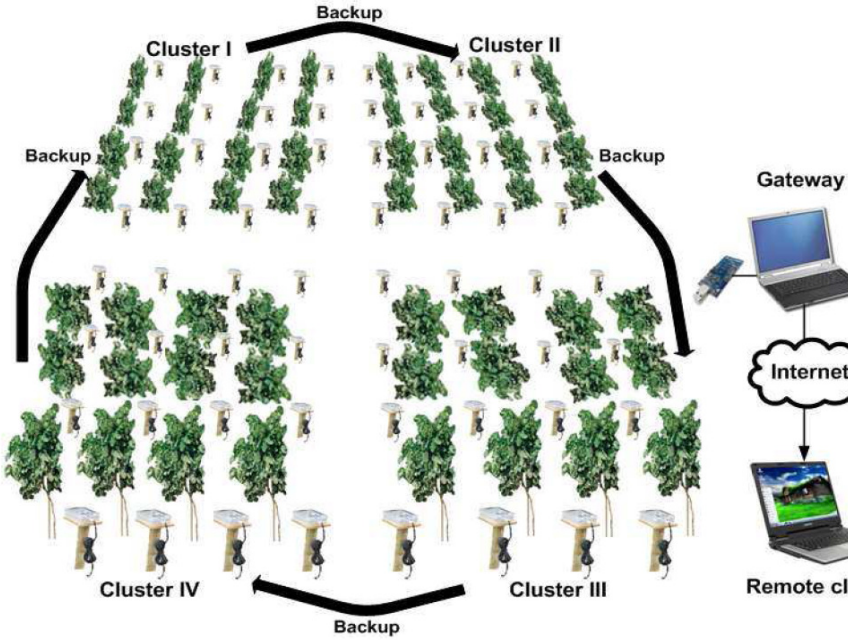
- Diverse sensing capabilities together with geographic coverage
- Resilience to faulty data and component failures
- Storage of data to the network as well as remote access either synchronously or asynchronously
- Long deployment times; self-organization

Encountered problems: (like in LOFAR-Argo Project)

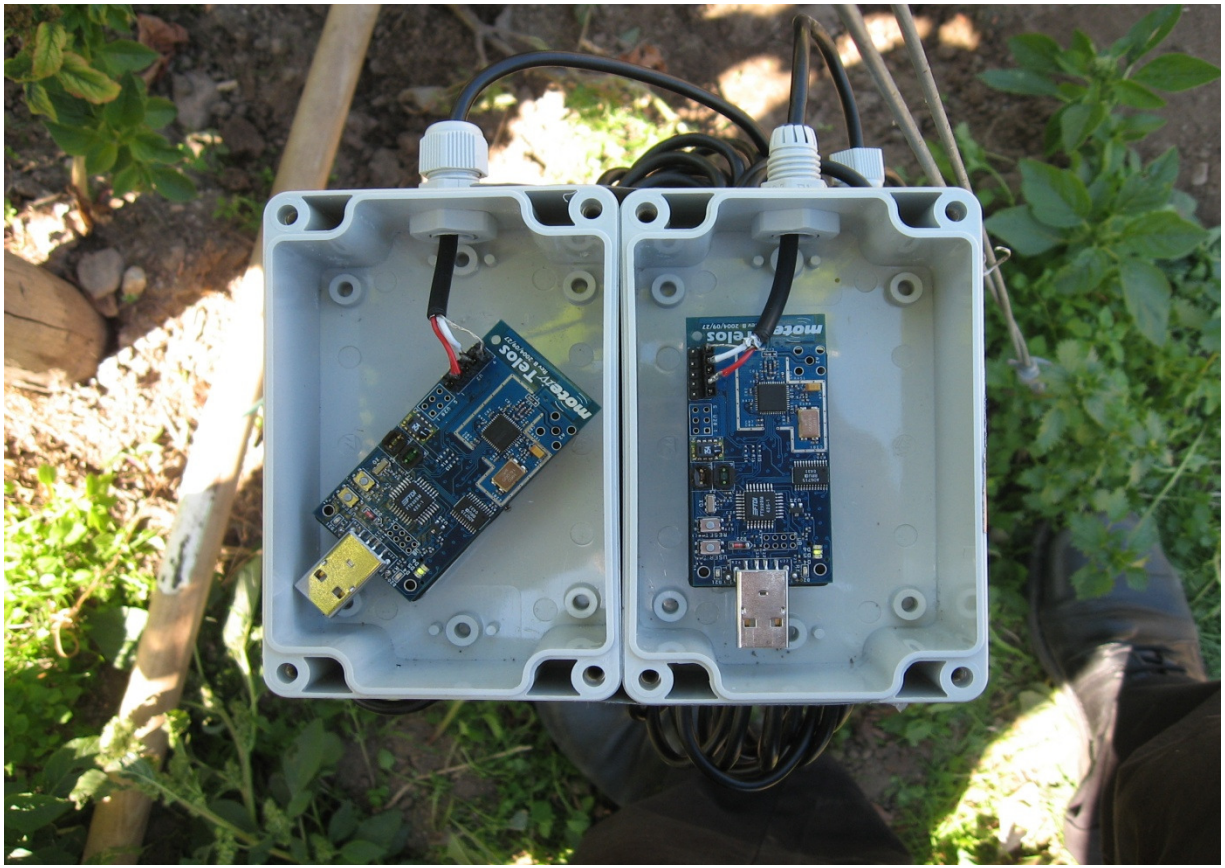
- Insufficient software engineering
- Incompatible modules
- Unforeseen side effects between modules

Additional problems:

- Harvester does not like sensor nodes
- Metal container influence wireless communication



Sensor nodes



Realflex project (2008-2010)

Water works

Standards,
existing architektur

Biogas facility

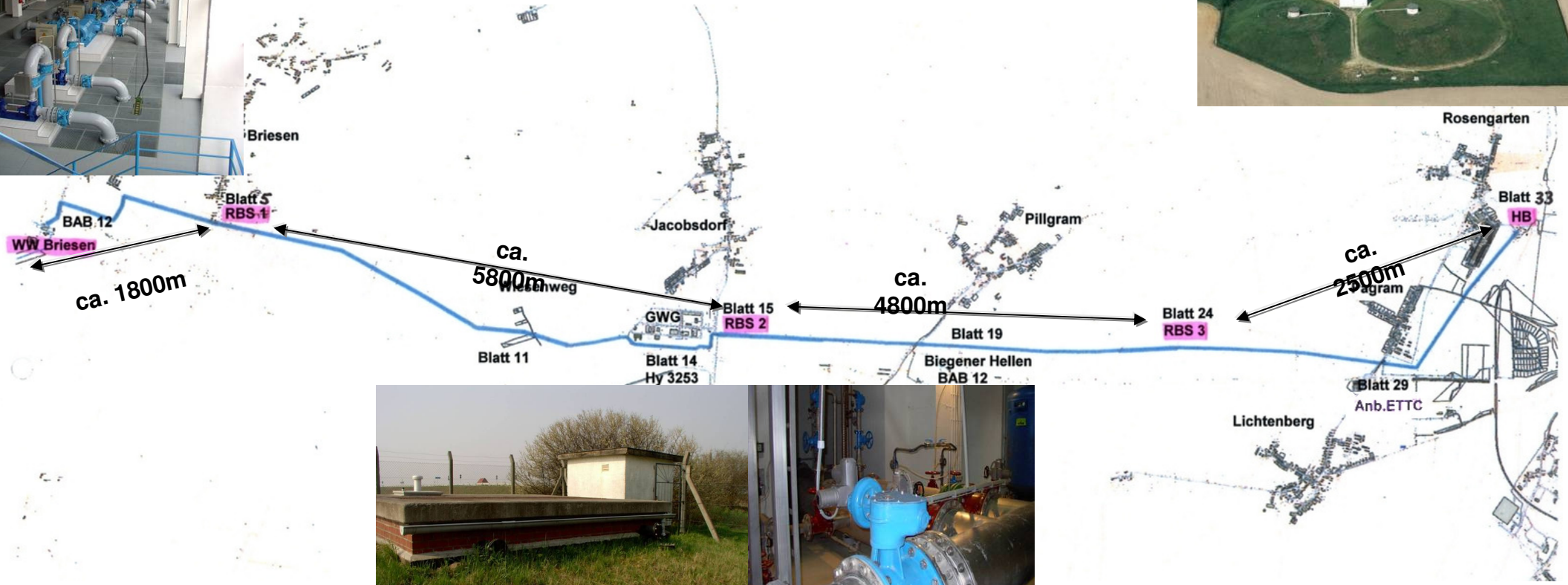
large distance,
local intelligence

Roboter cell

Small latency,
dependability

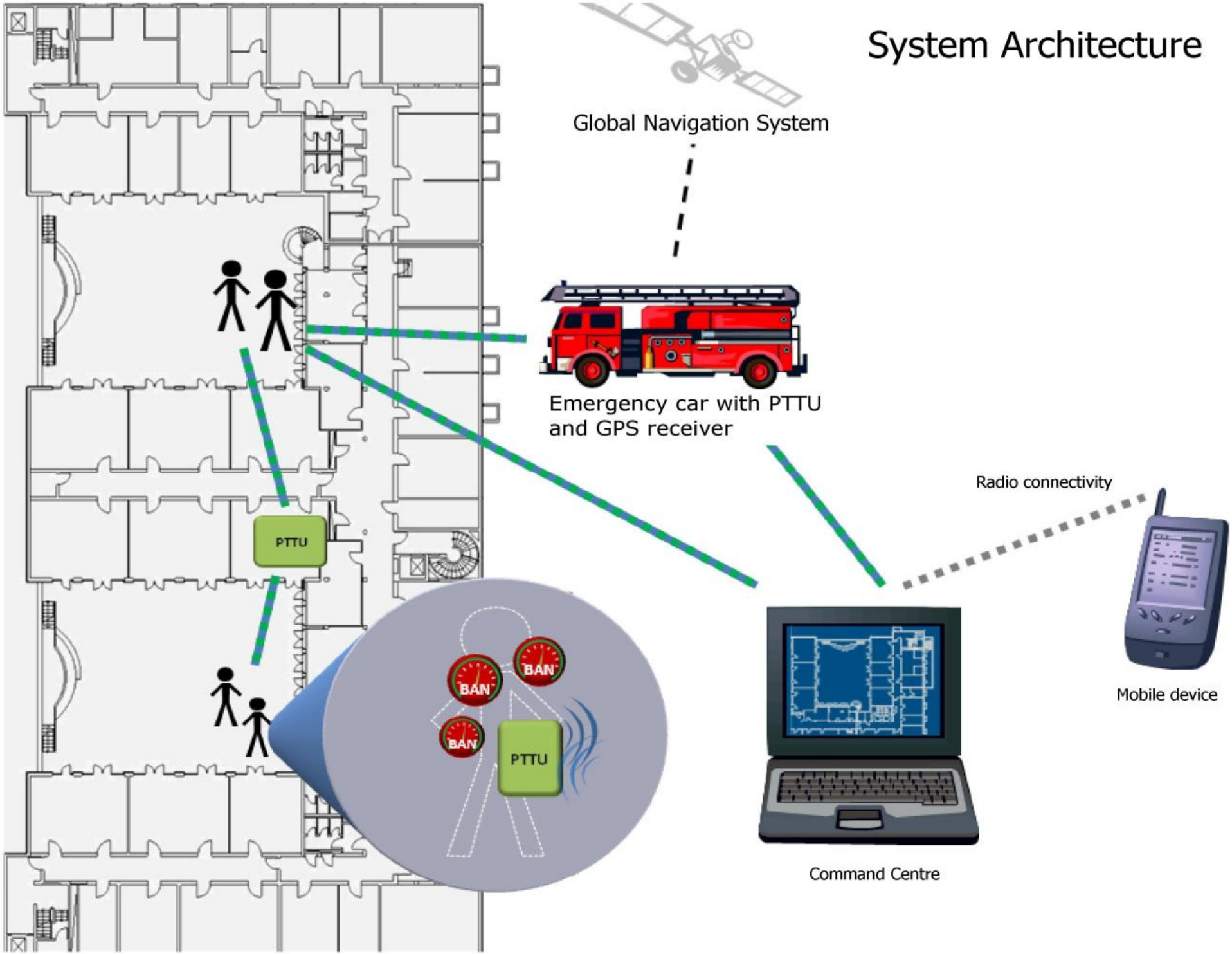
wireless architecture for industrial automation

Scheme of water mains

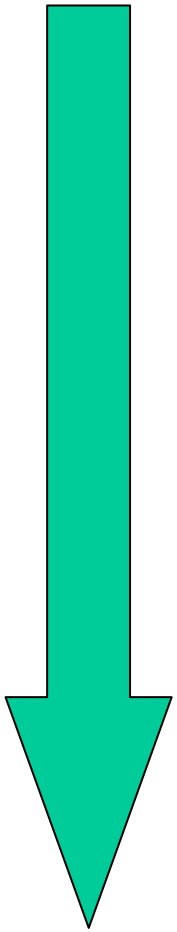


Projekt: FeuerWhere

System Architecture



Timeline of Sensor Network Research



2000 -

- **Studies, basic research, small demonstrations**

2006 -

- **Prototypical real world applications**
  - **Developed by specialized expert groups**
  - **Very expensive (several person years)**

???

- **Broad spectrum of reusable application frameworks**
  - **Programmable by domain experts**
  - **Easy and cheap software and hardware setup**

Motivation

Huge future market for Wireless Sensor Networks:

- environmental and structural health monitoring
- military and homeland security applications
- control in offices and private households

→ **Strong security, safety and privacy requirements**

Problem: How to realize and manage this security?

Sensor Nodes have severely scarce resources:

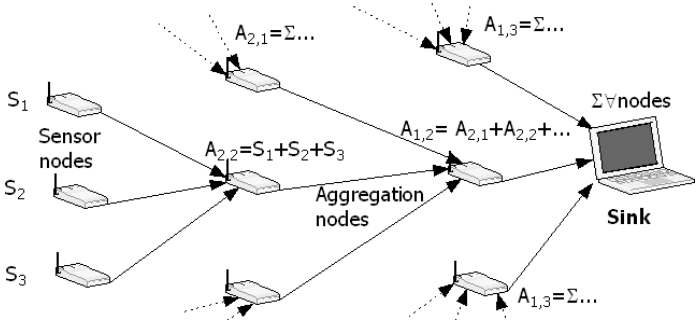
- **Energy**
- **Processing power**
- **Memory**

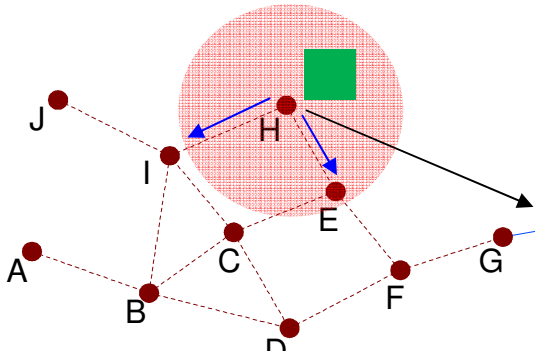
Problem: Trade-Off: Security ←→ Performance

Motivation (2)

There are a lot of solutions for isolated problems:

- Secure and dependable routing
- Good encryption
- Dependable and secure distributed data storage

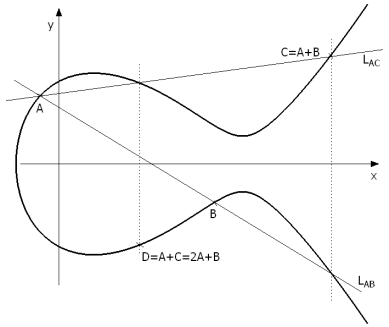




Problem: How to exploit all good solutions in one system?

Implementation of sensor nodes is a lot manual work

- Error-prone
- Not objective
- Needs a lot of time → Expensive



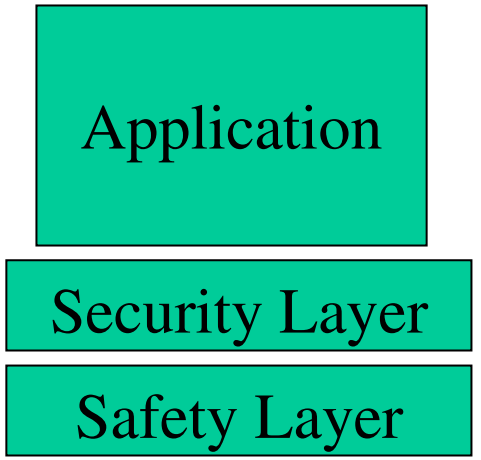
Problem: Secure WSN solutions have to be economically reasonable

How to design secure and dependable WSNs?

- **Today:**
  - -develop actual application first
  - -Attach some security stuff later

  →no satisfying security & safety

  →Lot of processing overhead



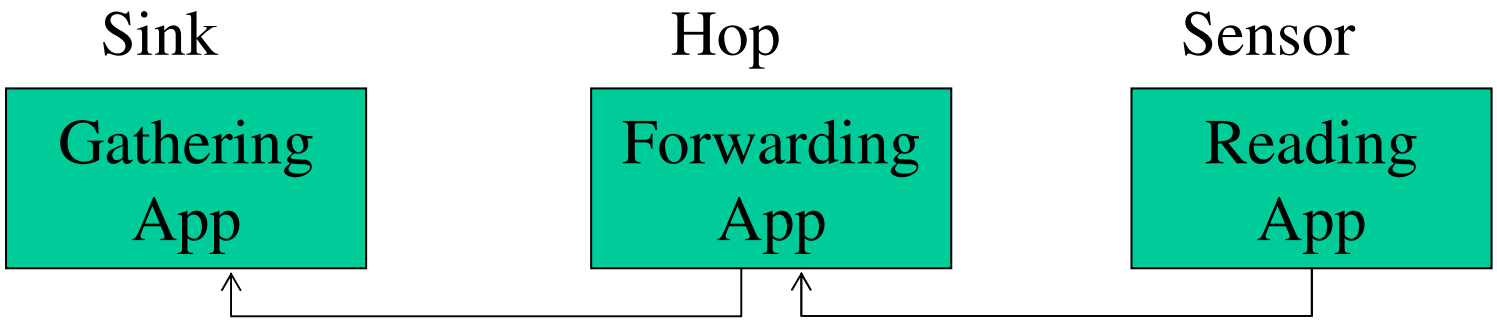
- **Required:**
  - -Development of integrated safe and secure application

  →Less protocol overhead

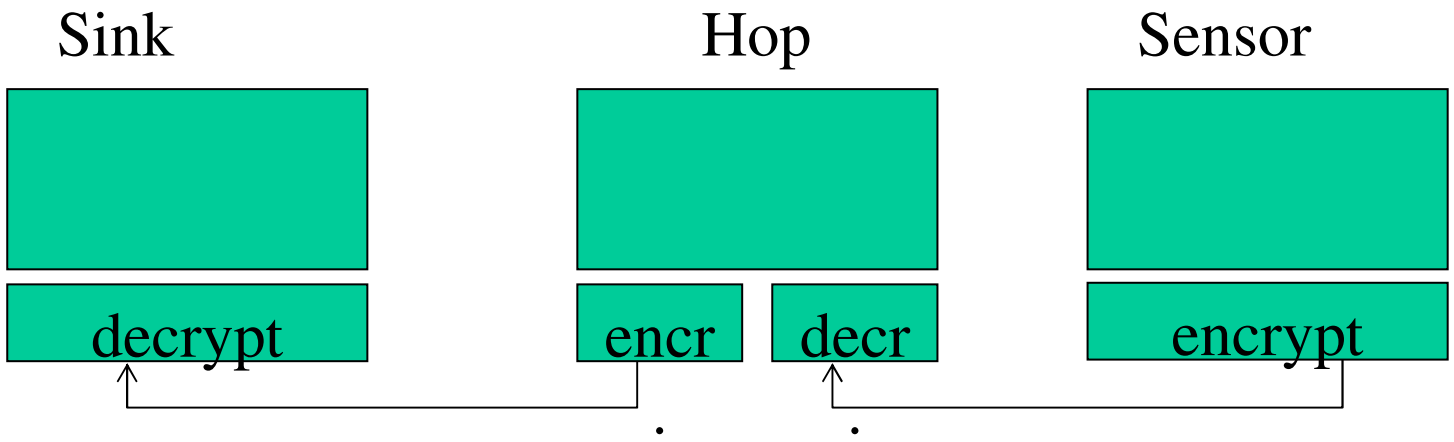
  →But development overhead

Example for possibly wrong design

Design unprotected application

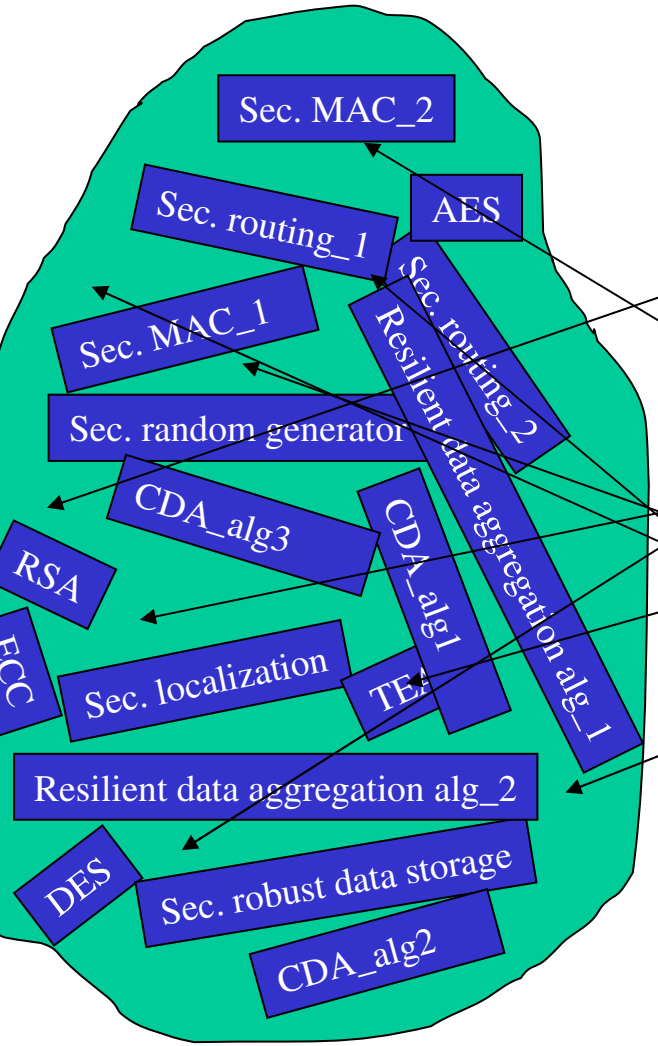


Secure implementation with encryption in MAC



Goals / Vision

Bunch of Solutions



Application

Sensor node HW

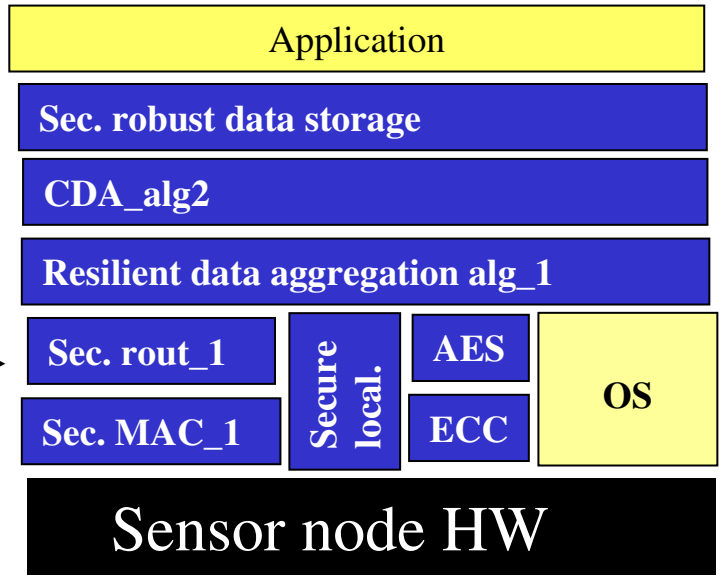
Req.

Configuration and Management Module

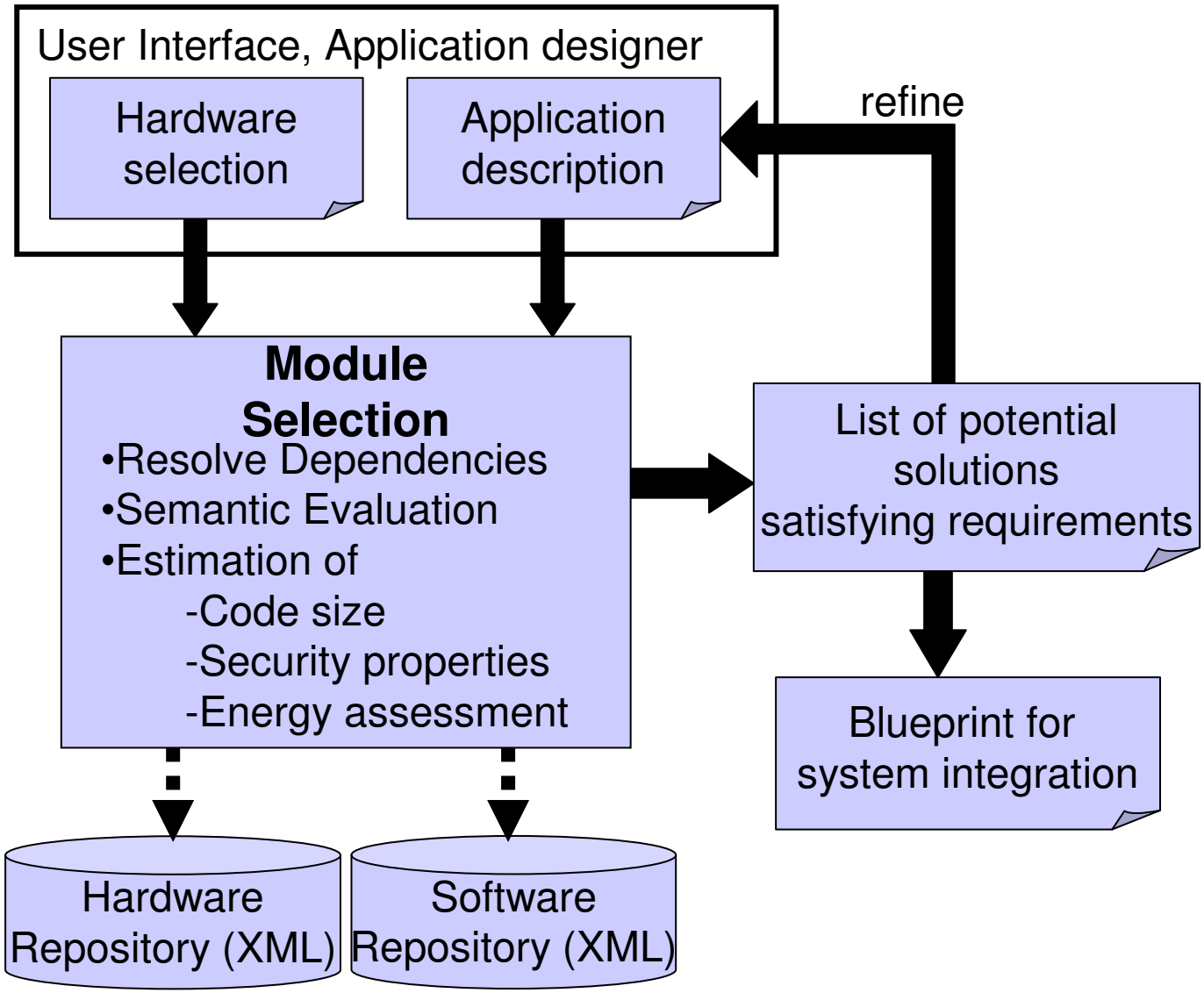
1. Req. vs features of modules
2. Interoperability of modules
3. Security of combination

Tailor made security architecture

System



The configKIT Approach

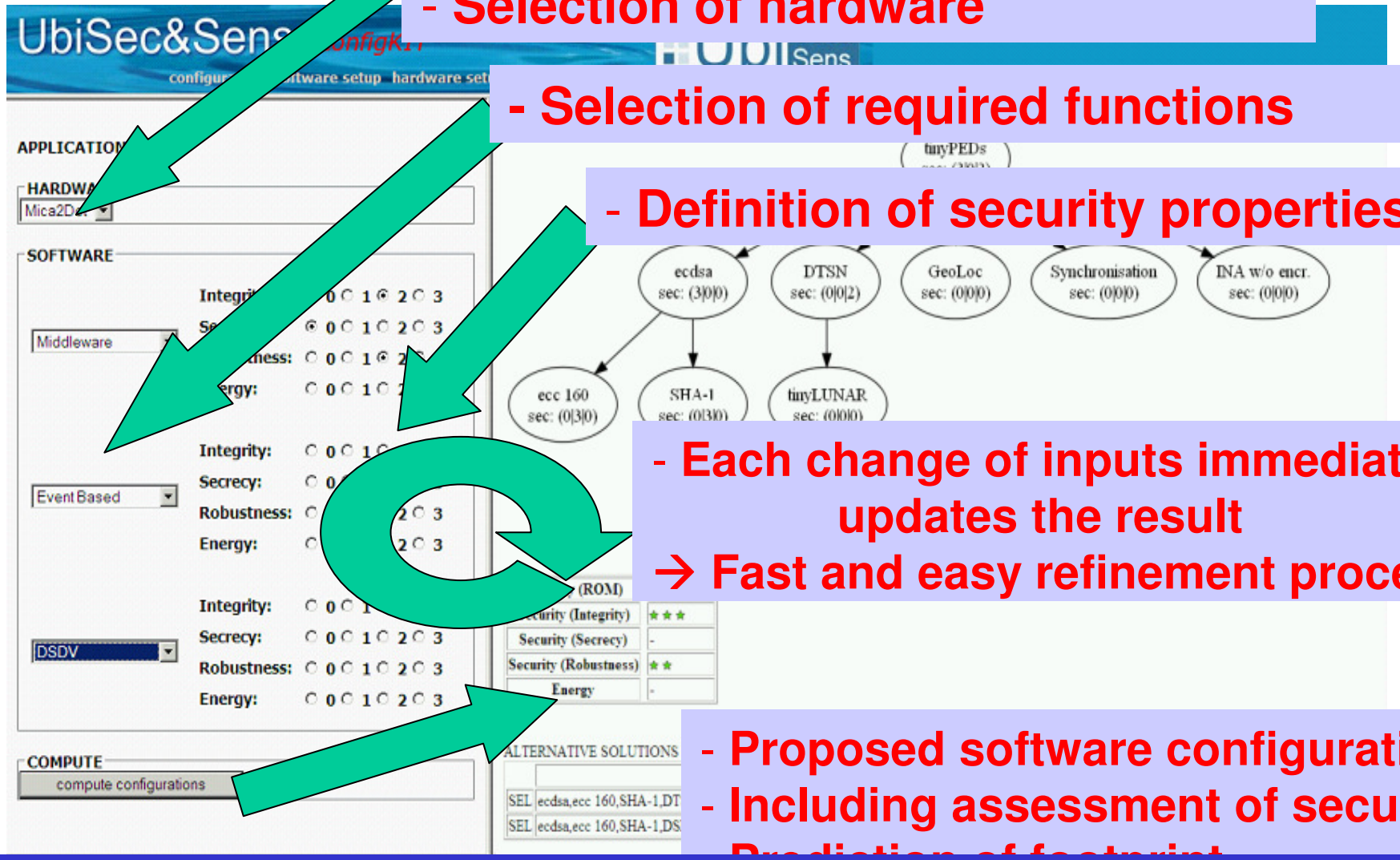


configKIT for Application Designers

- Selection of hardware

- Selection of required functions

- Definition of security properties

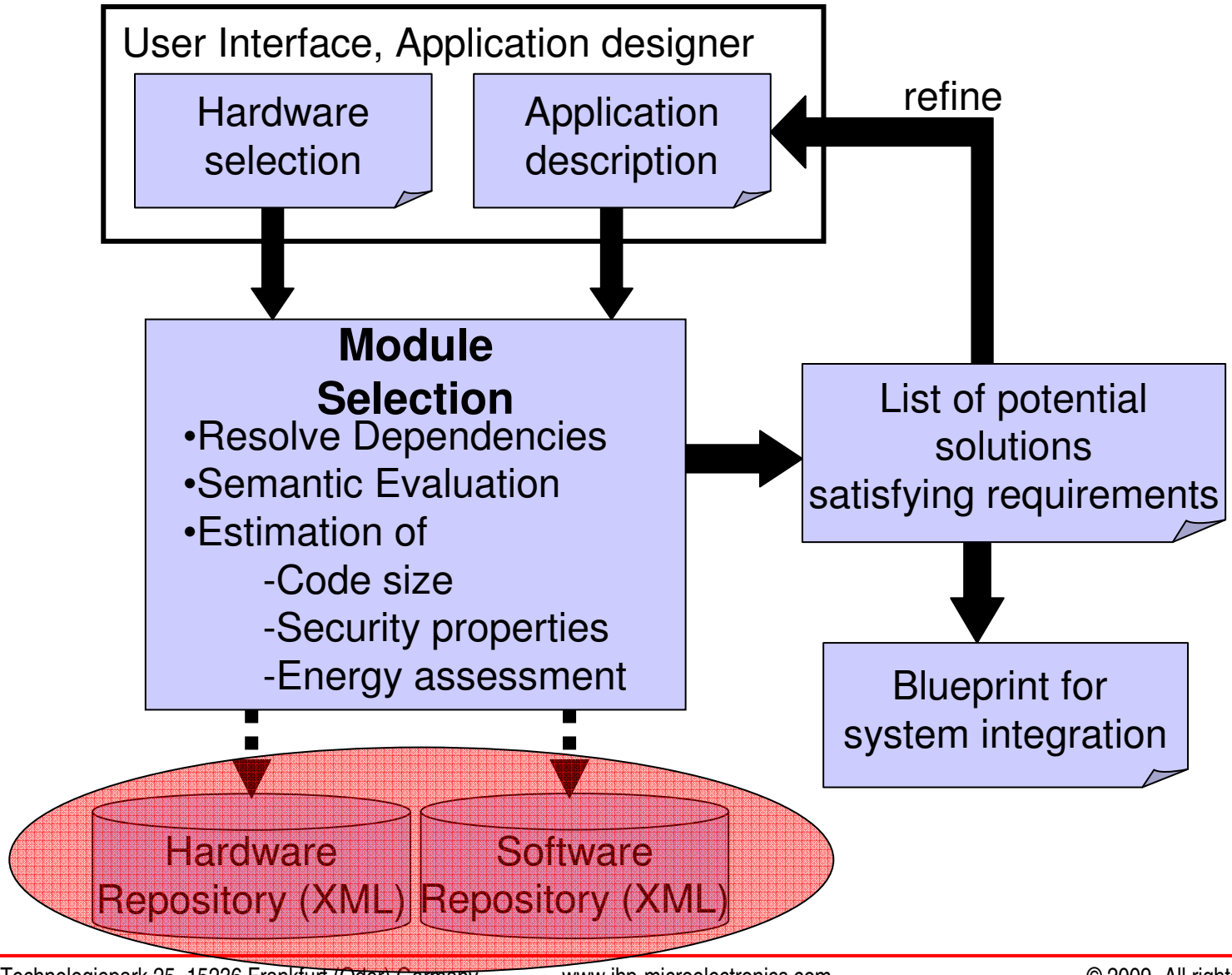


- Each change of inputs immediately updates the result
→ Fast and easy refinement process

- Proposed software configuration
- Including assessment of security level
- Prediction of footprint

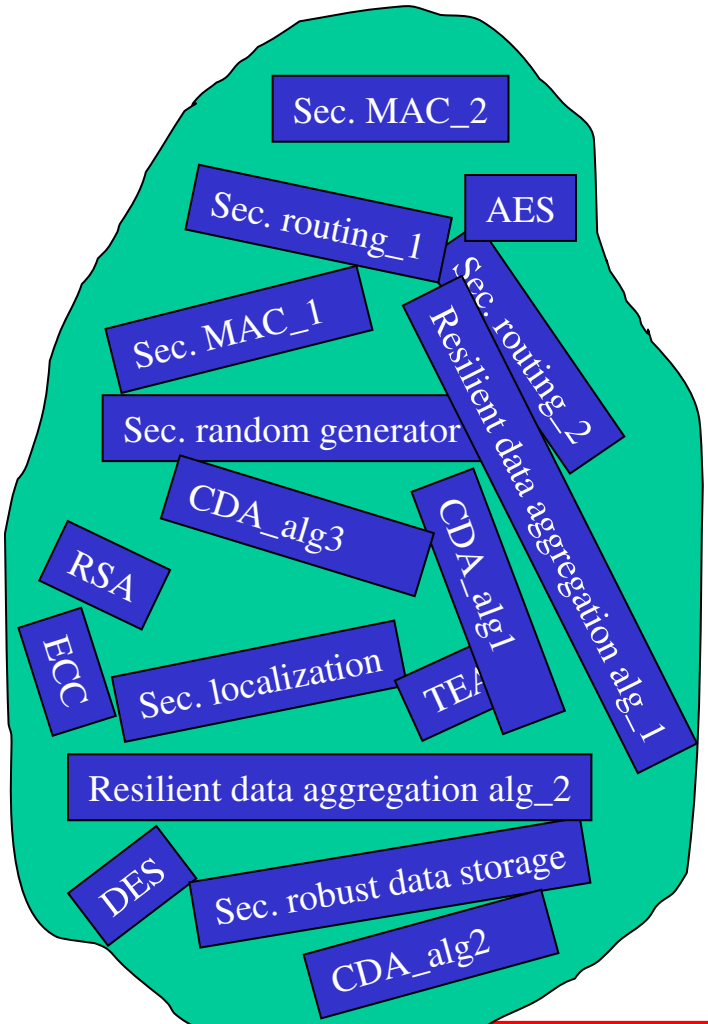
Online demo available at: http://www.ist-ubisecsens.org/downloads/configKIT/configkit.php

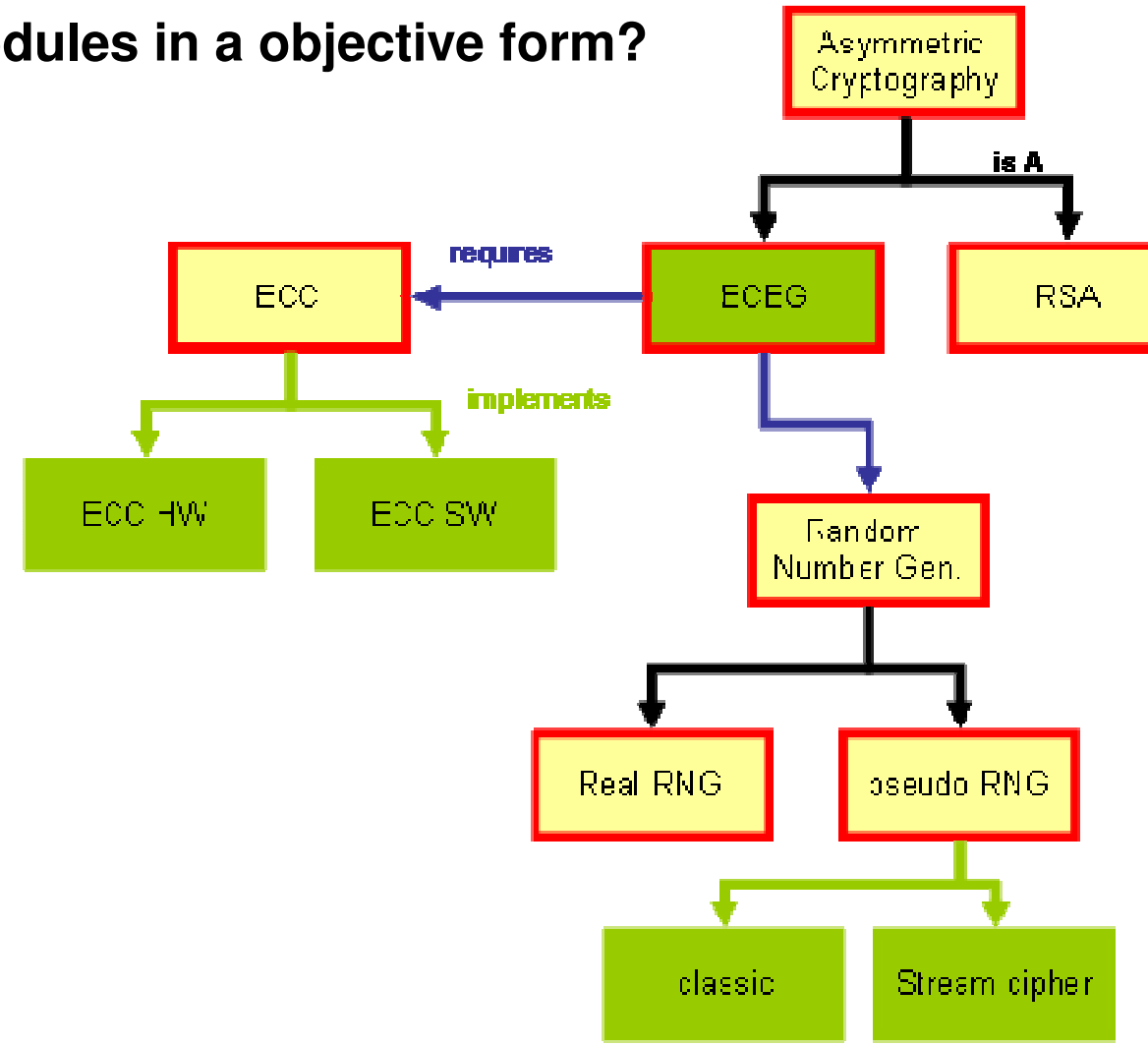
The configKIT Approach – Setup of Repositories



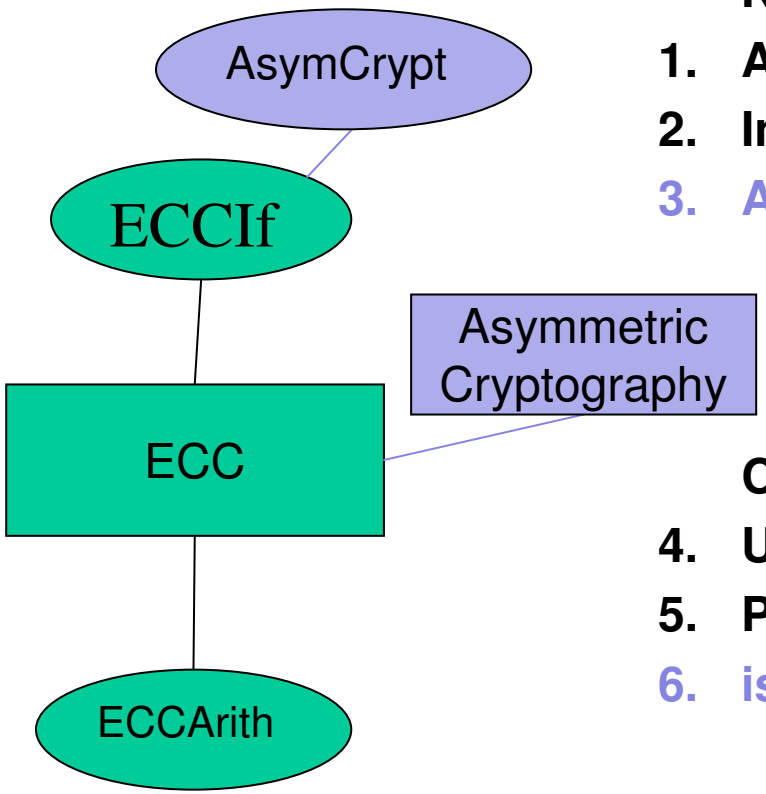
Challenge (1)

How to present the bunch of modules in a objective form?





Structure of Software Repository



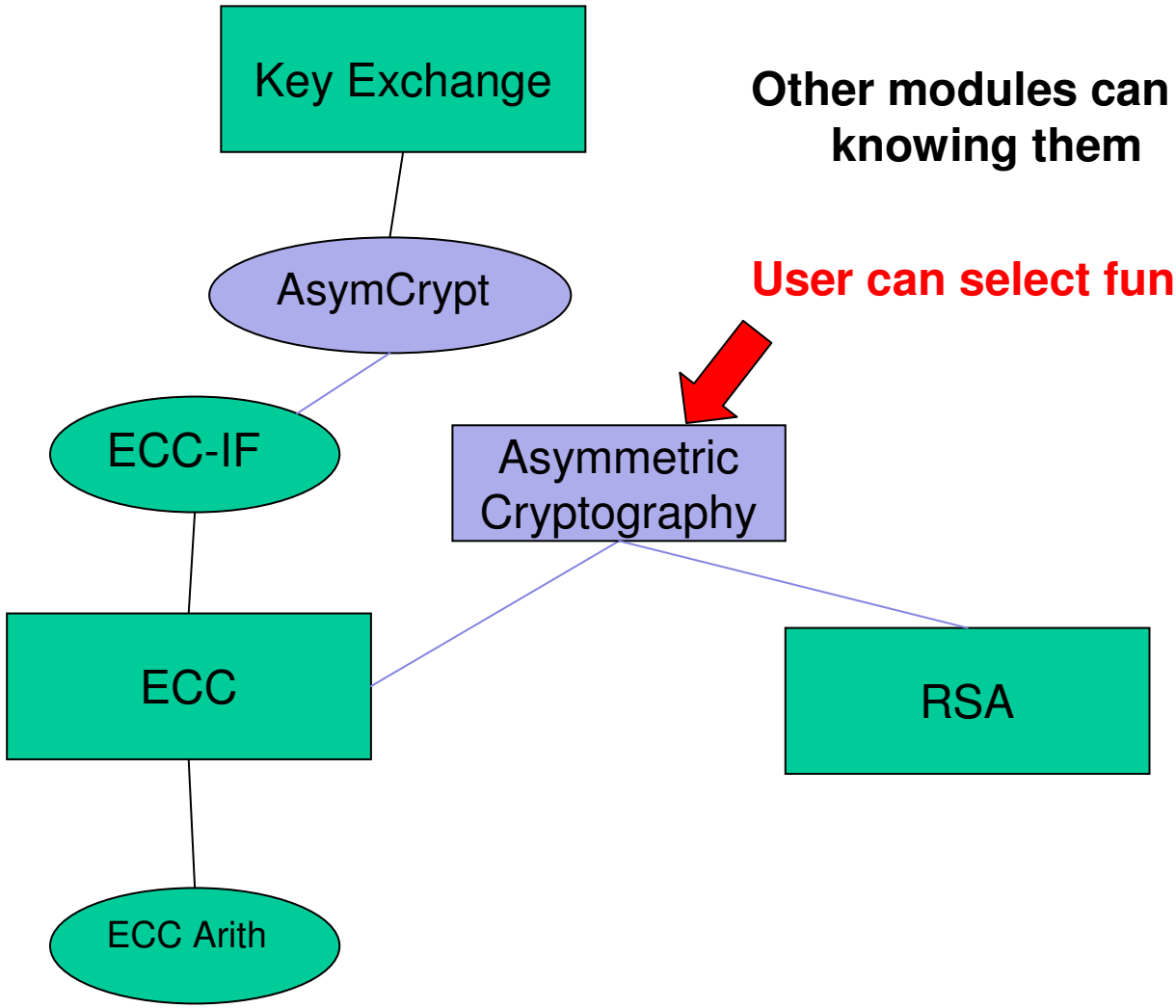
Nodes:

1. **Actual Module**
2. **Interfaces they use and provide**
3. **Abstract Modules and Interfaces**

Connections

4. **Uses**
5. **Provides**
6. **isA**

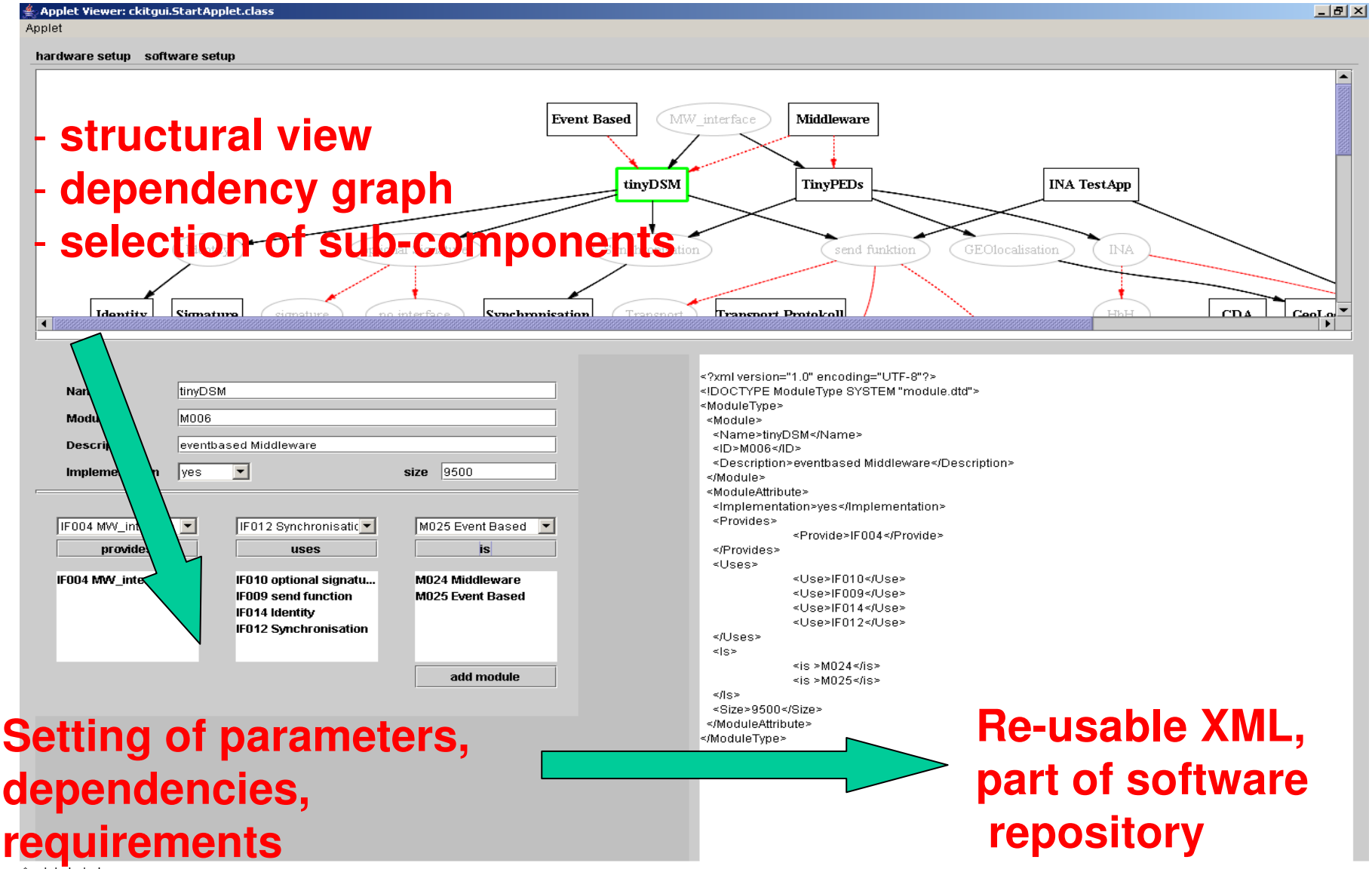
Structure of Software Repository



Other modules can use interfaces without knowing them

User can select functions in informal way

Setup of Software Repository



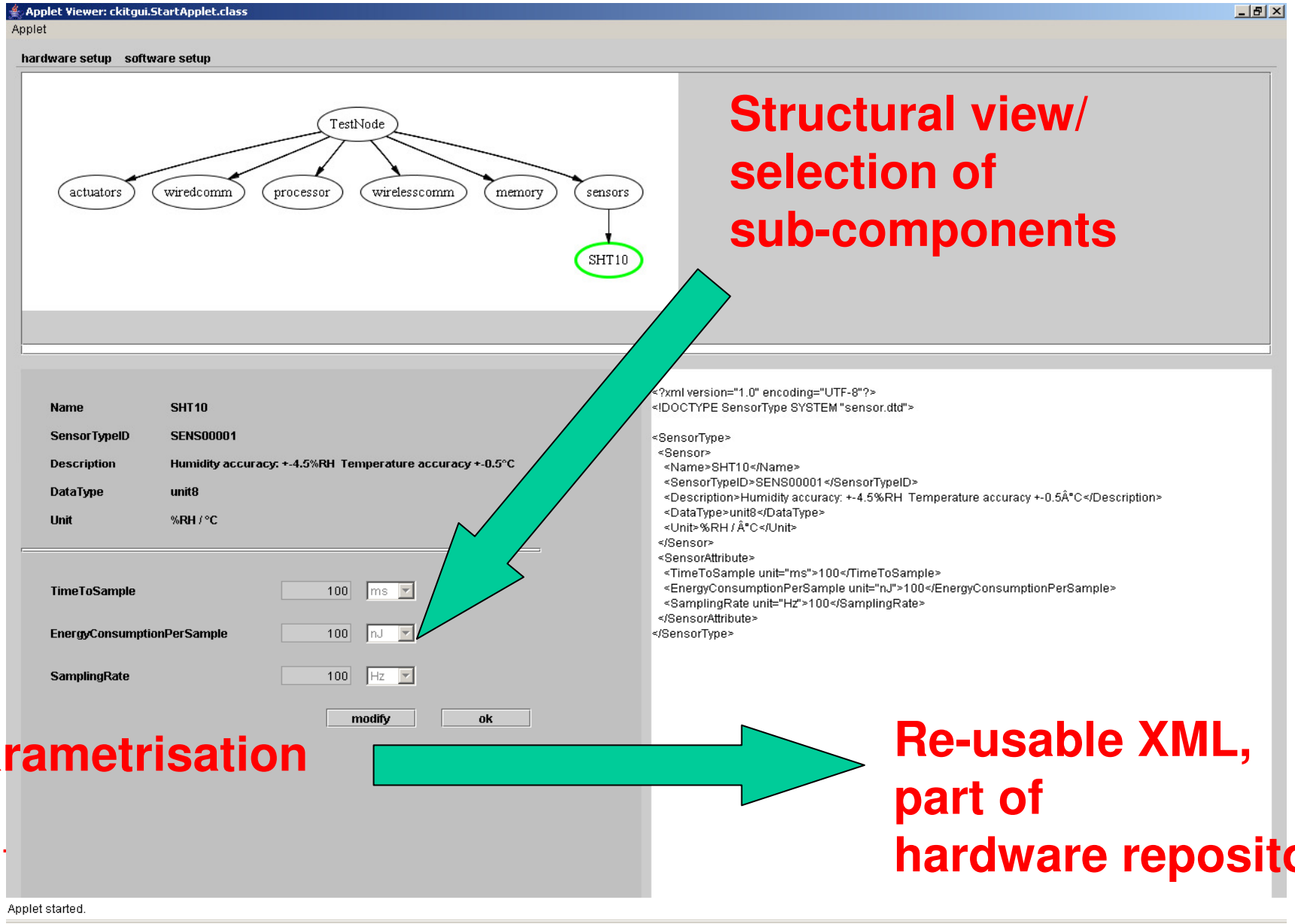
Setting of parameters, dependencies, requirements

Re-usable XML, part of software repository

Example Module Description

```
<SoftwareComponentType
  Description="Elliptic Curve Digital Signature Algorithm"
  IsStatic="true" Name="ECDSA" Version="0.1">
   <EnergyConsumption>0</EnergyConsumption>
   <CodeMemorySize>1468</CodeMemorySize>
   <DataMemorySize>540</DataMemorySize>
   <PersistentMemorySize>0</PersistentMemorySize>
   <Provides>
     <SoftwareInterfaceType Alias="ECDSA" SoftwareInterfaceTypeId=""/>
   </Provides>
   <Uses>
     <SoftwareInterfaceType Alias="ECC" SoftwareInterfaceTypeId=""/>
   </Uses>
   <SecurityParameter Name="Integrity" Value="4"/>
   <SecurityParameter Name="Concealment" Value="2"/>
   <SecurityParameter Name="Robustness" Value="1"/>
 </SoftwareComponentType>
```

Setup of Hardware Repository



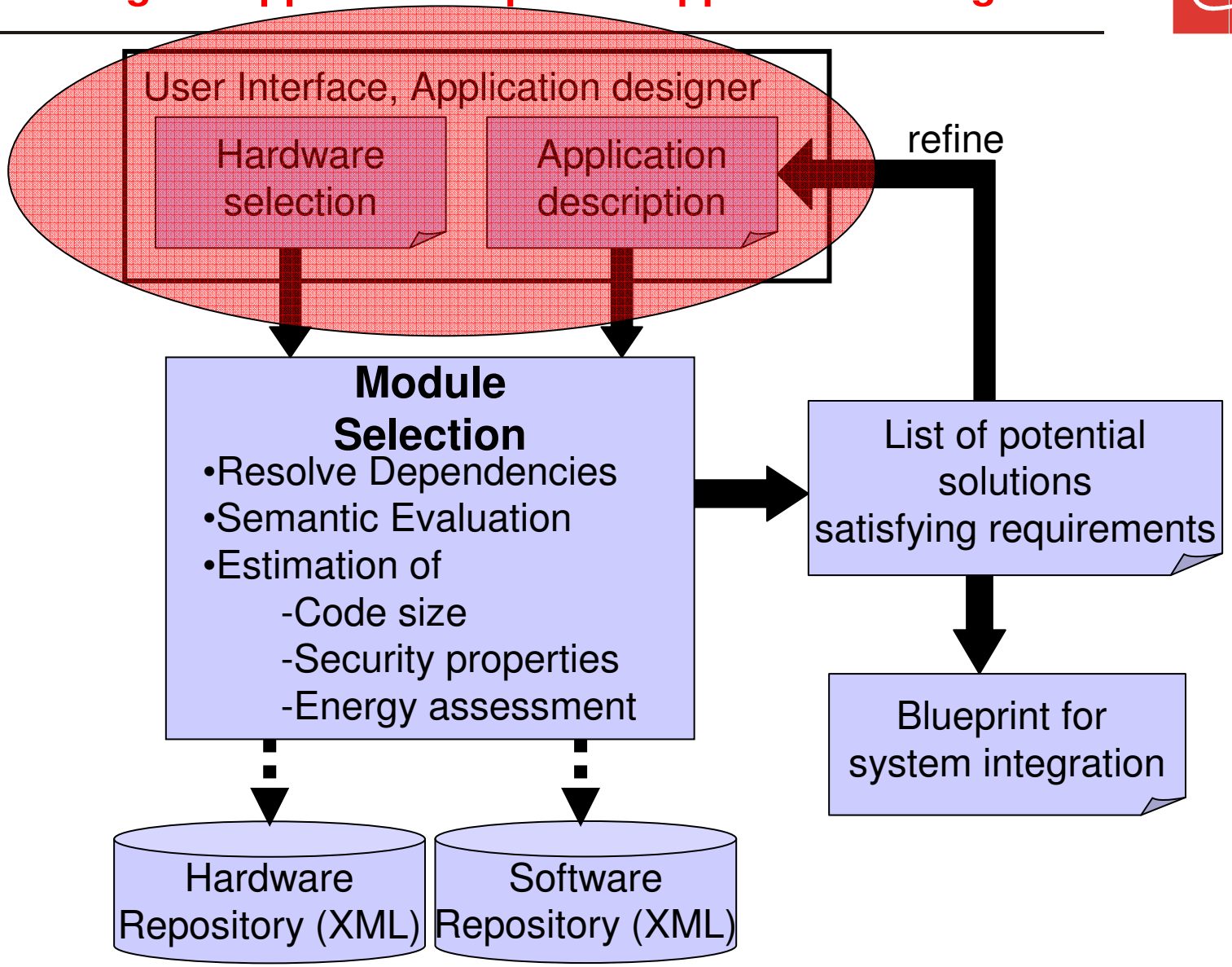
Parametrisation

Re-usable XML, part of hardware repository

Example Hardware Description

```
<SensorType>
  <Sensor>
    <Name>SHT11</Name>
    <SensorTypeID>10011</SensorTypeID>
    <Description>Humidity accuracy: +-3.0%RH  Temperature accuracy +-0.4°C</Description>
    <DataType>unit8</DataType>
    <Unit>%RH / °C</Unit>
  </Sensor>
  <SensorAttribute>
    <TimeToSample unit="ms">10</TimeToSample>
    <EnergyConsumptionPerSample unit="mJ">10</EnergyConsumptionPerSample>
    <SamplingRate unit="Hz">10</SamplingRate>
  </SensorAttribute>
</SensorType>
```

The configKIT Approach – Input for Application Designer



Challenge (2) – App description & Module Selection

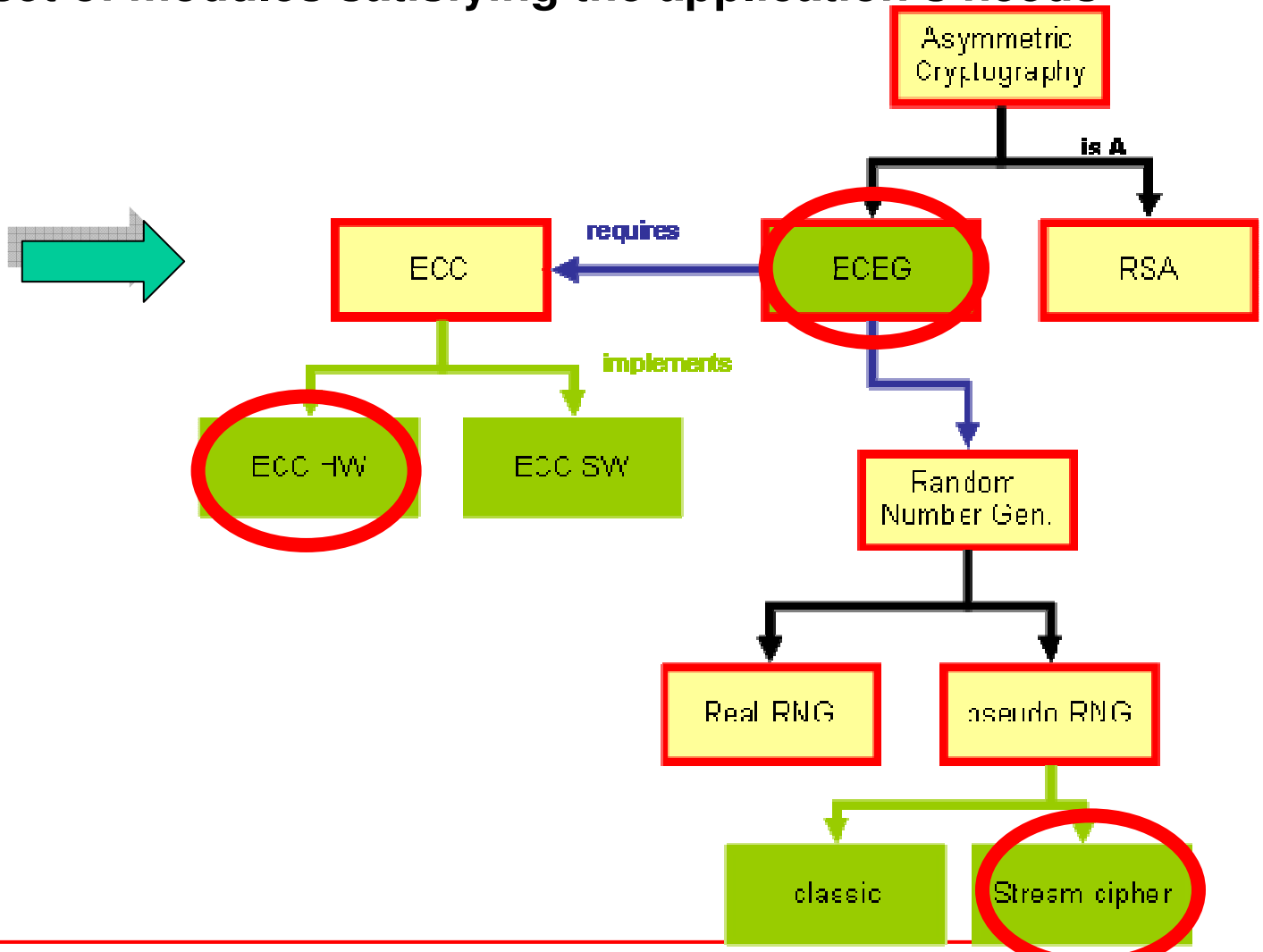
Selection of the set of modules satisfying the application's needs

Application:

- Need for Public Key Cryptography
- 20 operations per hour
- Life time > 6 months
- Hardware: MicaZ

Security Requirements:

- Data secure for 20 years



Selection: Current State

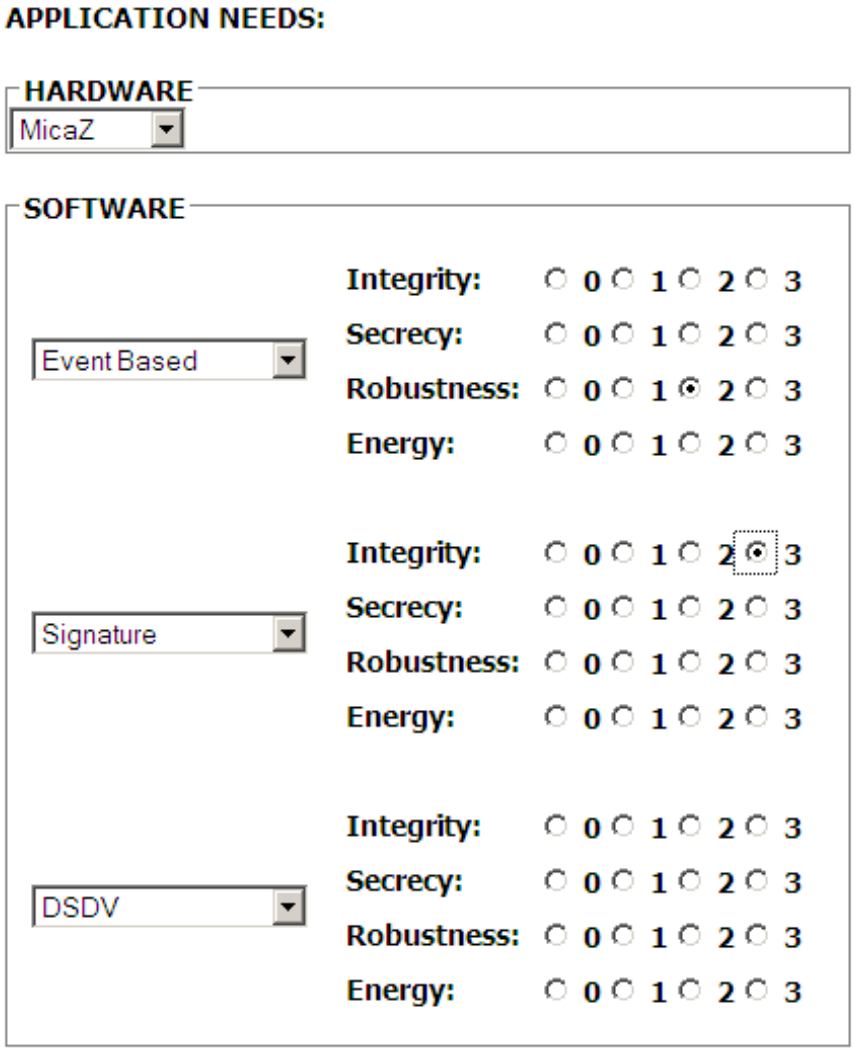
- **Selection of Hardware**

- **Selection of software modules**

  functional description

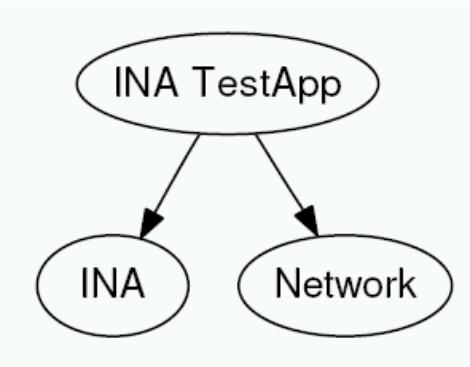
  or explicit modules

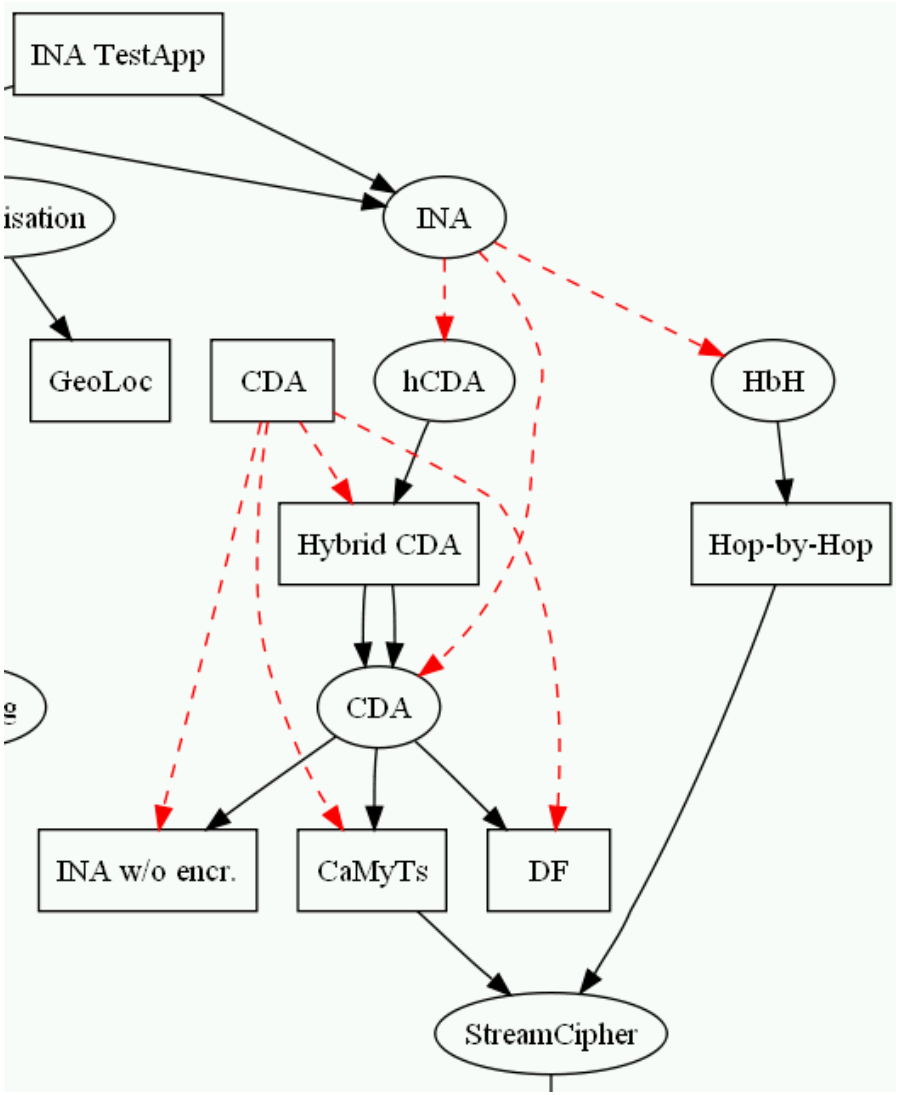
  + required parameters



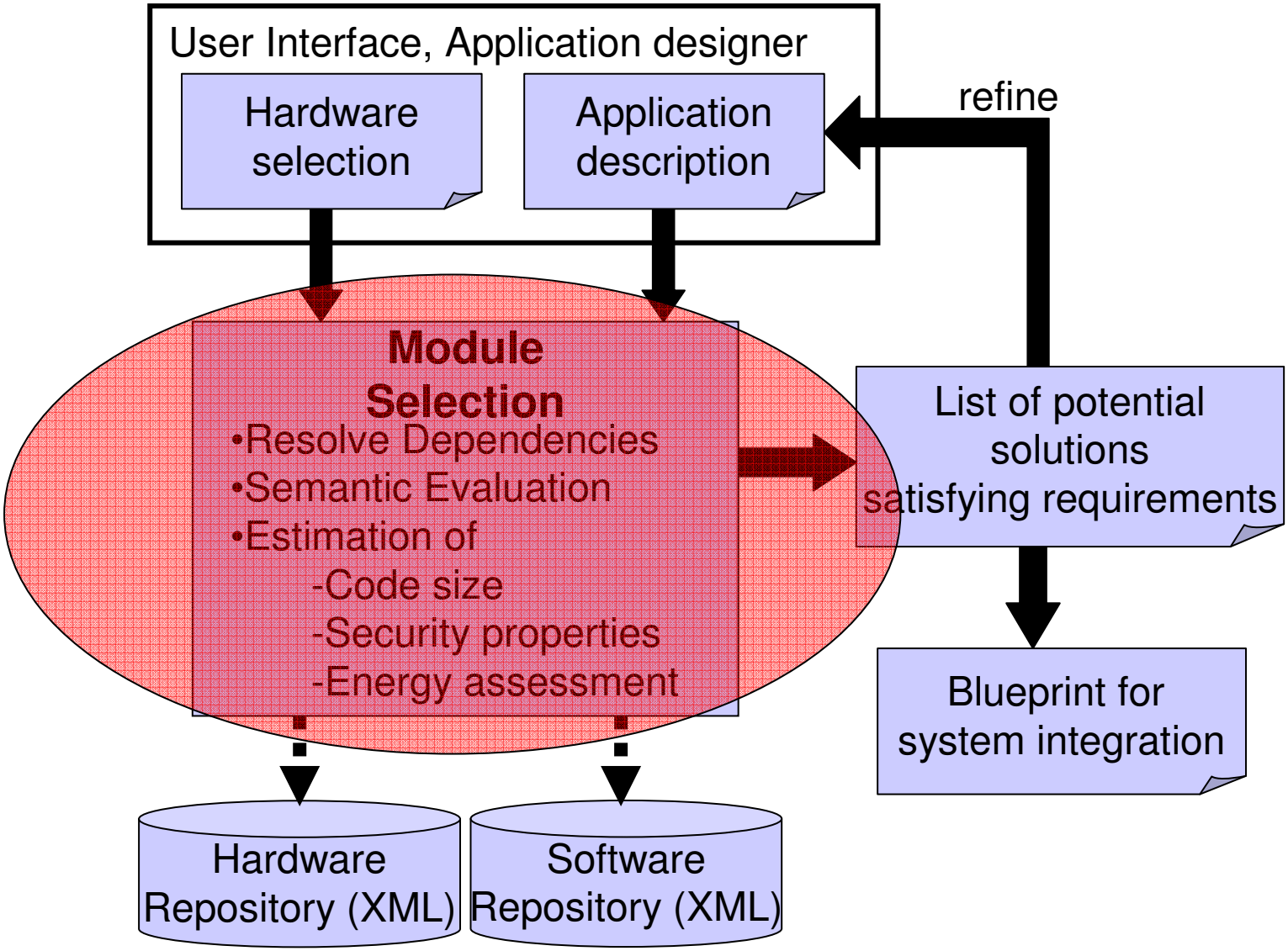
What‘s the application anyway?

Application is just another software Module as part of the Software Repository

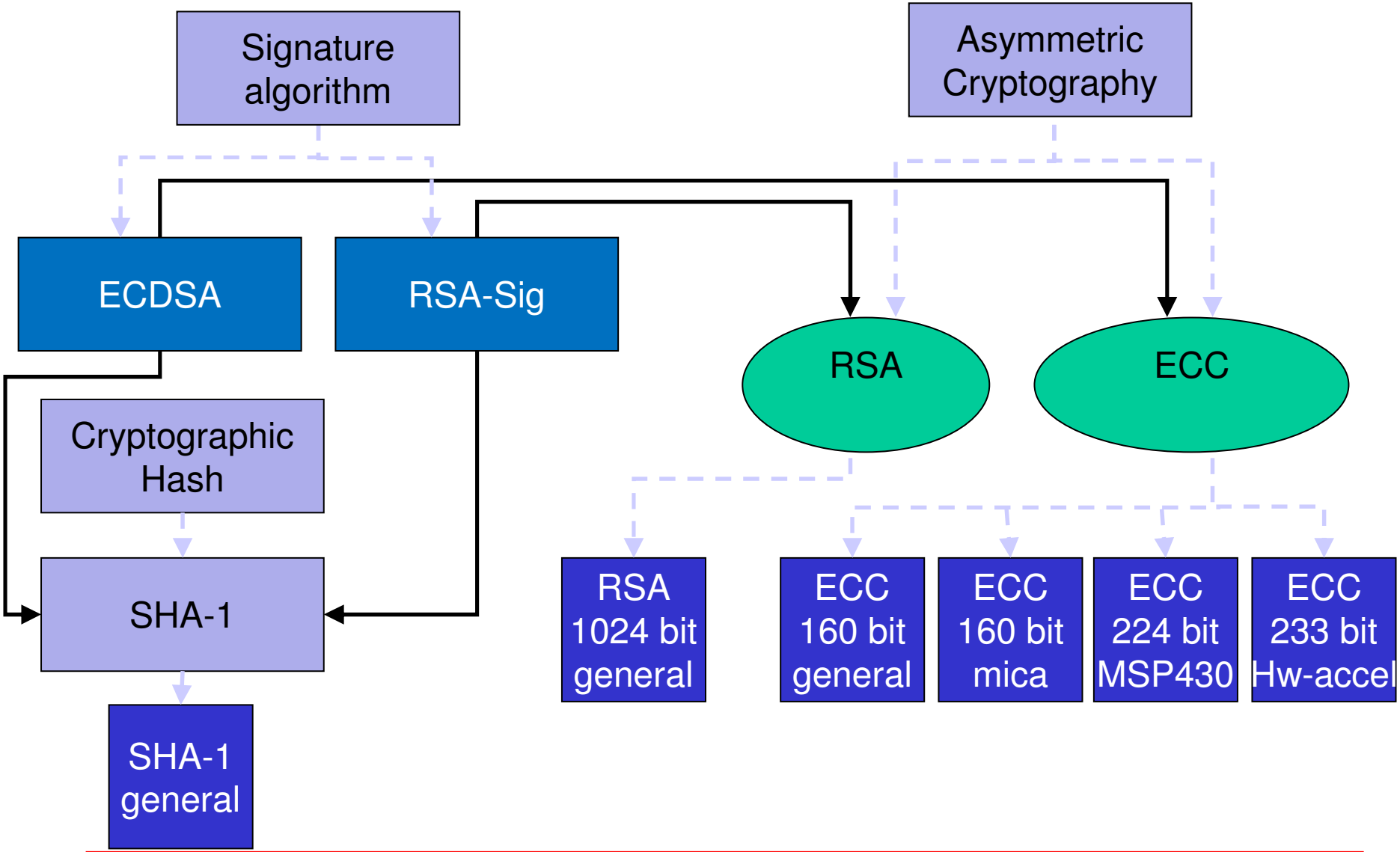




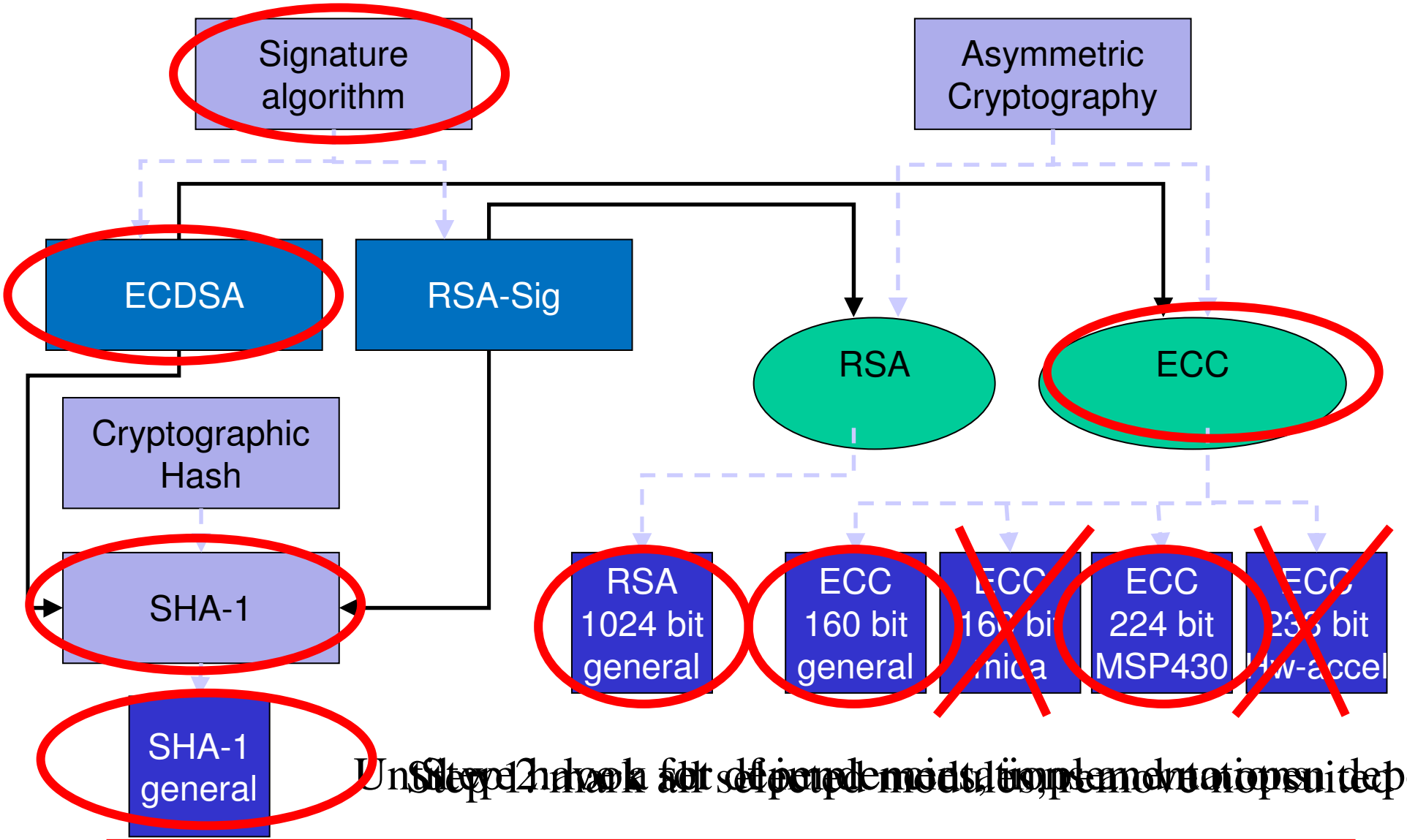
The configKIT Approach – Module Selection



Example (1)



Example (2) – Signature algorithm on MSP430



Step 1: mark all depended modules, remove unmarked

Step 2: mark all selected modules, remove unmarked dependenci

Optimizations

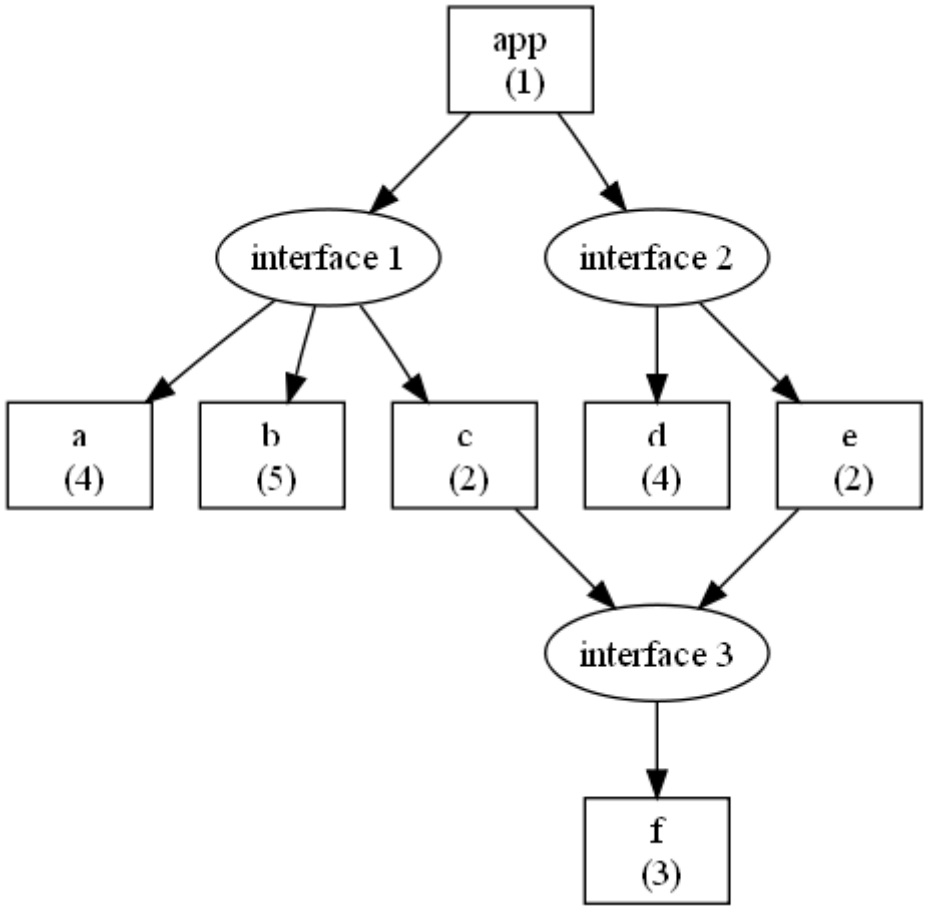
- **Original algorithm is NP complete**
  → Optimizations required

Approach:

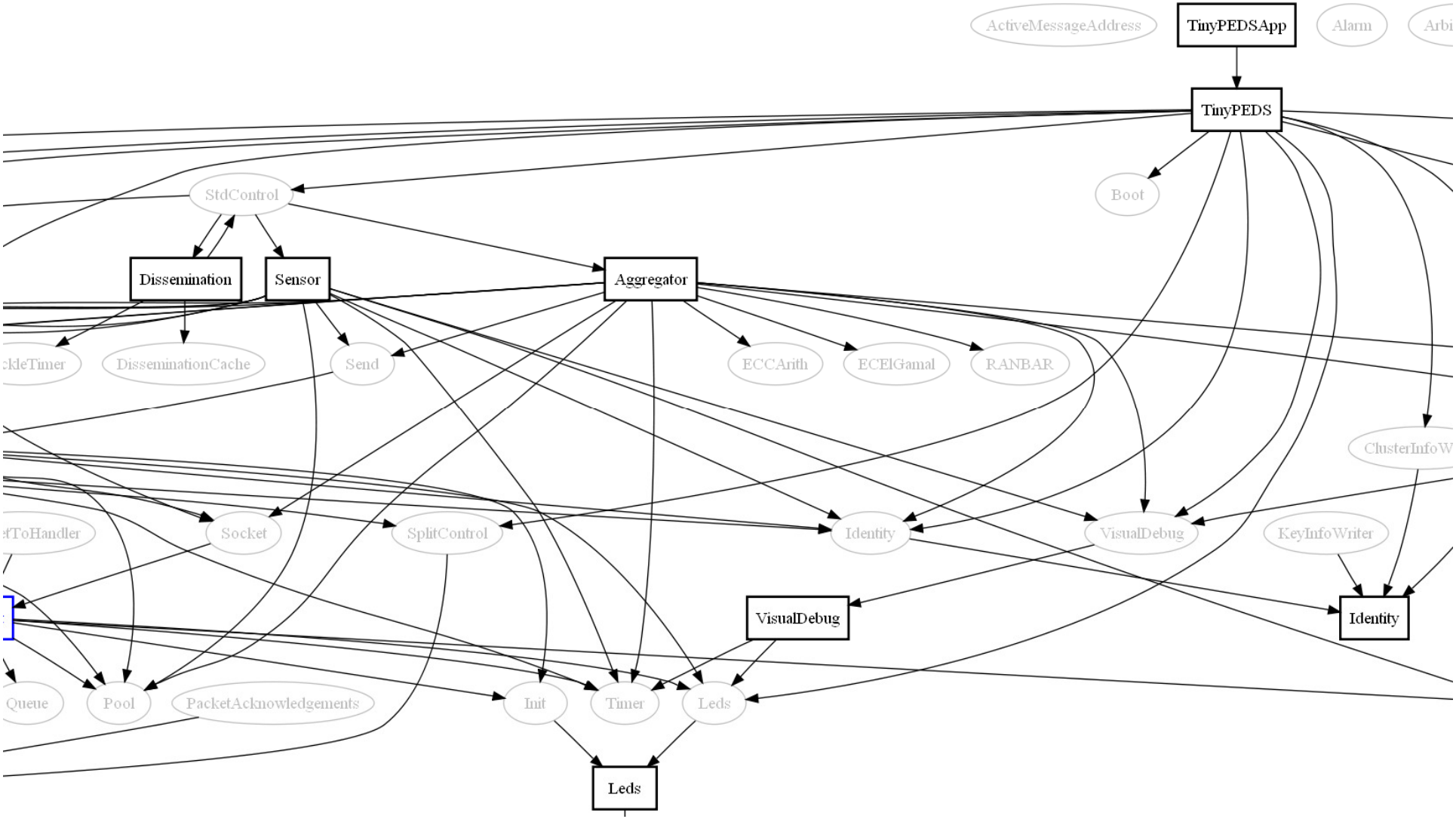
- **Remember decisions**
  - Do not follow unbeneficial sub-trees more than once

→Problems:

- Re-convergences (no actual tree)
- how make sure unbeneficial sub-tree is not better for another pre-selection?

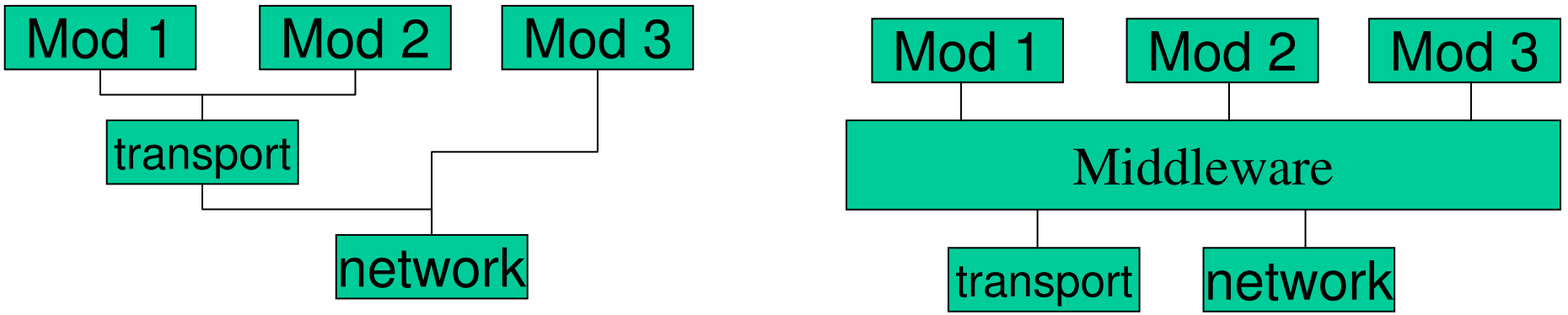


Reality



How to solve the model-reality-gap

- **Simplify reality**
  - **Unified interfaces**
  - **Backbone operating system/message controller/middleware**



- **Increase complexity of models**

Assessment Process

- **Memory:**
  - Addition of single modules
  - Problem: size(A+B) != size(A)+size(B)

    → Simple addition is rather an approximation (upper bound)

- **Energy:**
  - currently qualitatively (good, medium, bad)

    →Allows comparison of similar protocols

    →Not yet satisfying
  - Required: prediction of actual energy consumption (uJ/op)

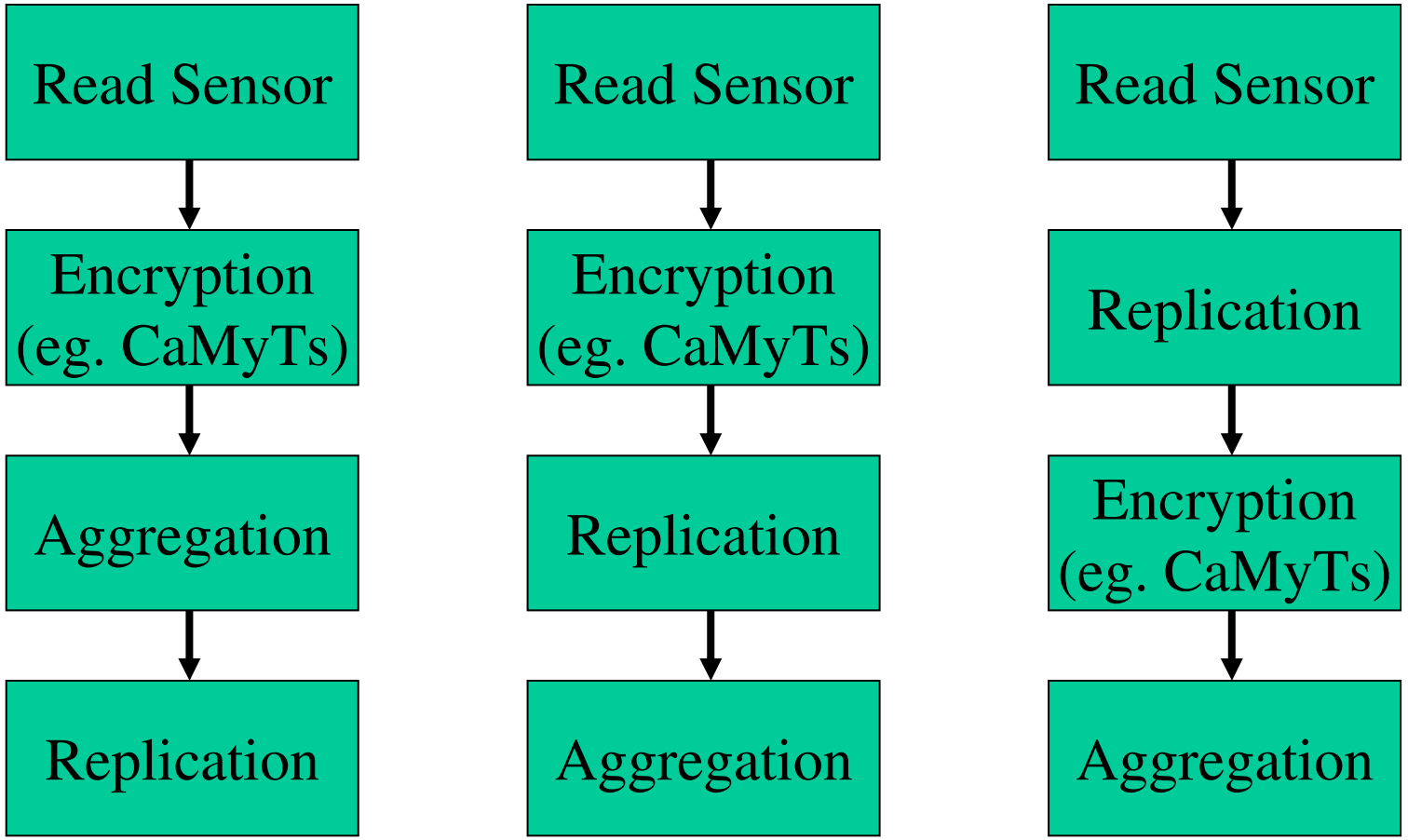
    →A lot of issues!

- **Security & Dependability:**

Challenge (3) – Proof of Security

Which flow is the best and why?

- **Dependability?**
- **Concealment?**



Proof of Security (2) – How it is currently done

•straightforward logic: (probabilistic security?)
secure module + not secure module = ??

•For concealment:
secure + not secure = not secure (the weakest module)

•For robustness (replication):
secure + not secure = secure (one replication is ok)

•For integrity:
secure + not secure = secure (one proof of integrity is ok)

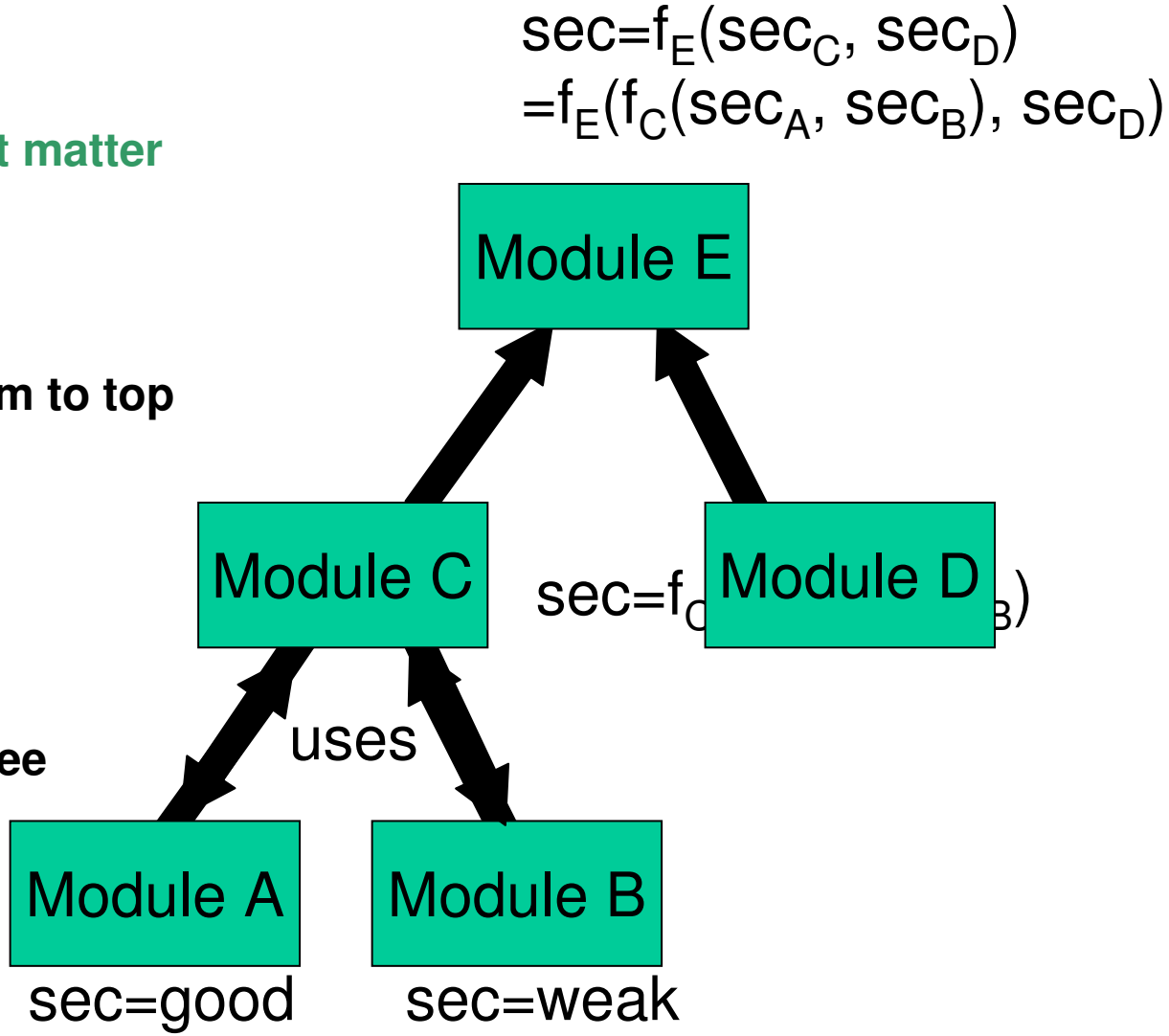
→ NOT REALLY SUFFICIENT → how to do it better?

Security Assessment

- **Security metric:**
  - **0 = no security/does not matter**
  - **1 = weak**
  - **2 = good**
  - **3 = strong**
- **Propagation from bottom to top of system**

- **Security properties propagate through the dependency graph**

- **Currently support of three security properties:**
  - **Secrecy**
  - **Integrity**
  - **Robustness**



Security Metric

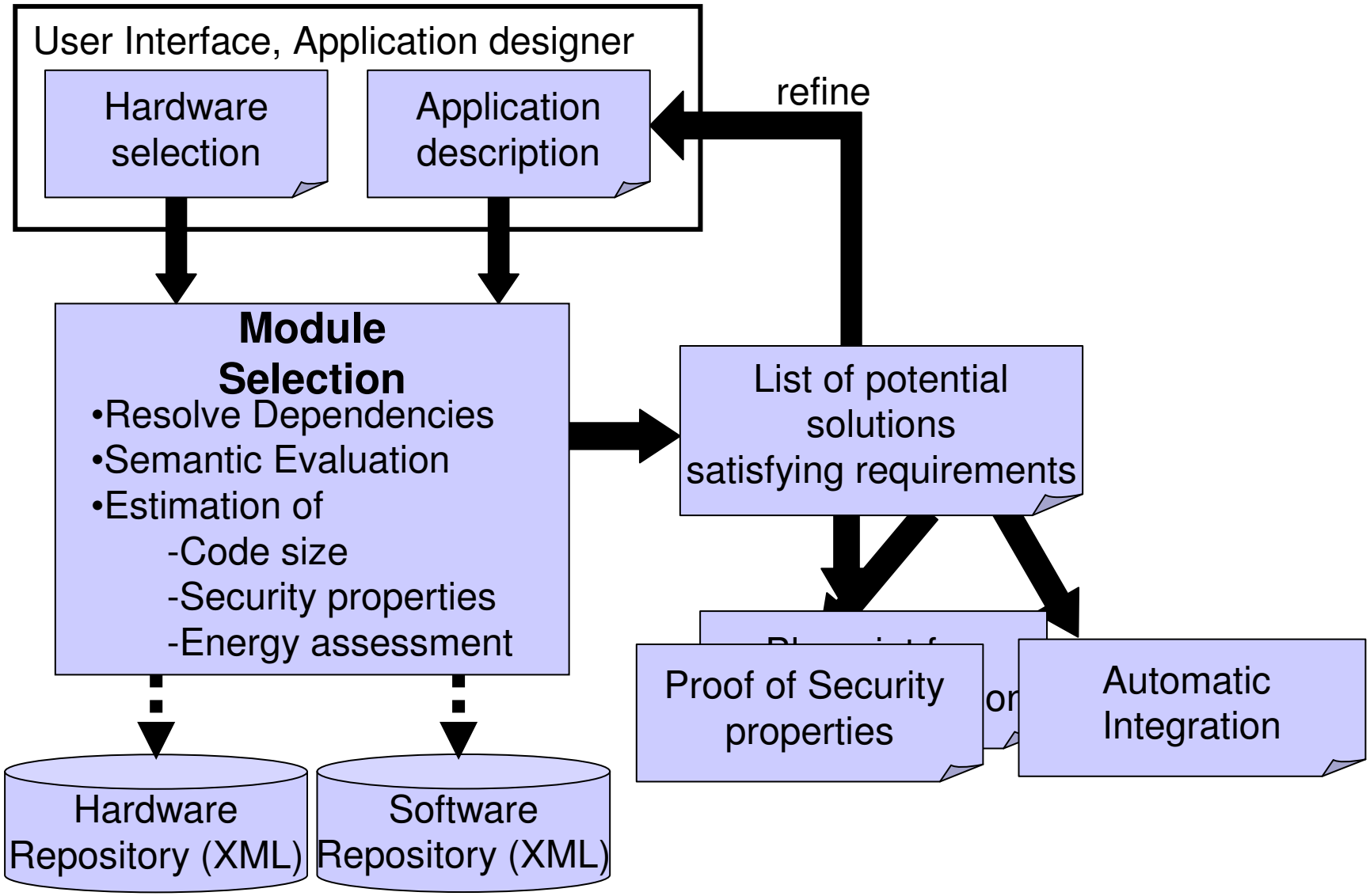
Security class	Attacker	Attacker tools	Budget
0	No security	attack can be succeed 'by accident'	
1	curious hacker	common tools	< 10,000$
2	organized attacker (academic, crime)	special tools	< 100,000$
3	large organized attacker (crime, government)	highly specialized tools, laboratory	> 100,000$

An algorithm belongs to class c if
it resists all attacks from attacker groups smaller than c.

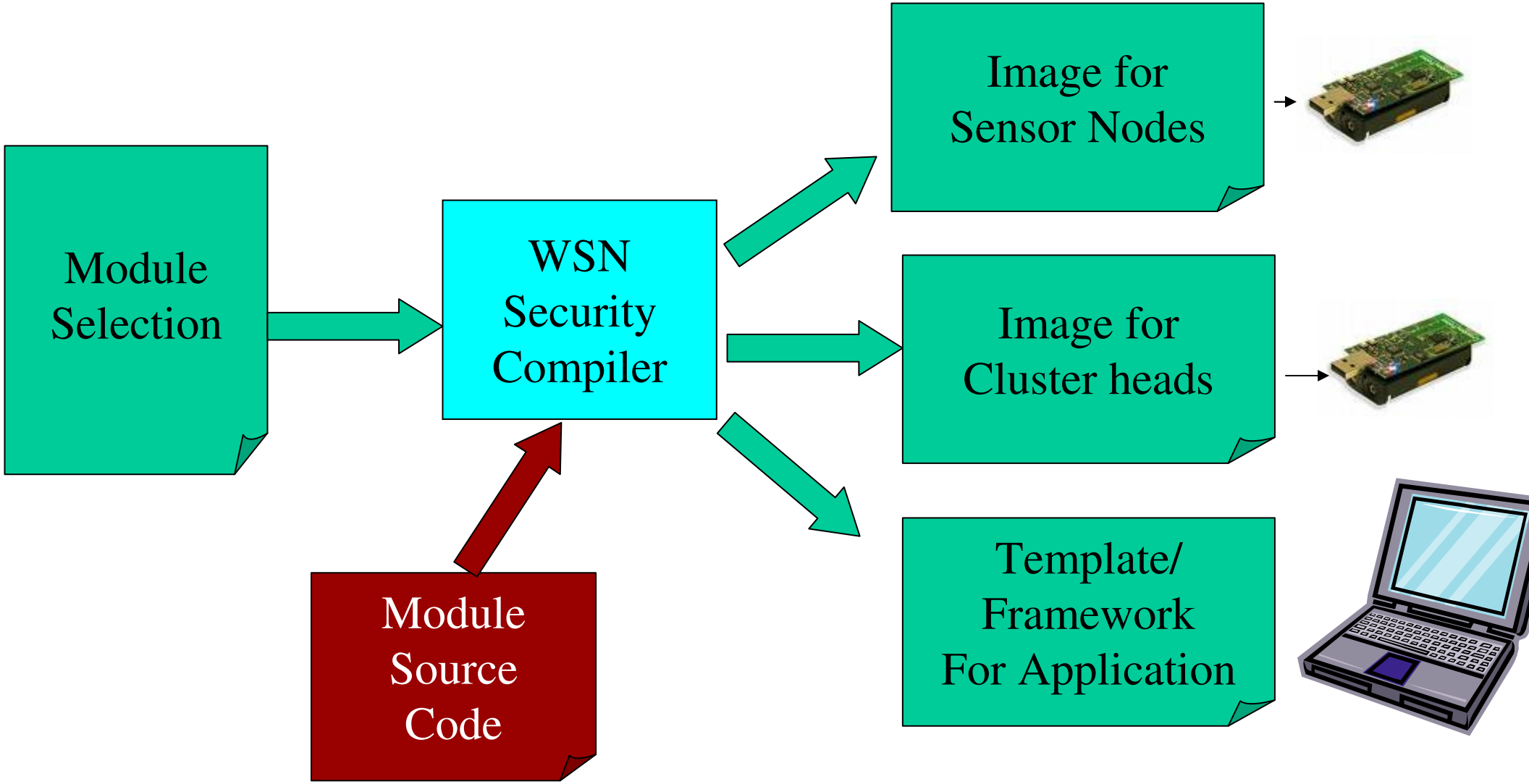
Similar metrics for other properties?

- **Dependability / Safety?**
- **Maintainability?**
- **Energy consumption?**
- **Memory consumption?**

The configKIT Approach – further work



Challenge (4) – Automatic Integration



Conclusions

- **Wireless Sensor (and Actuator) Networks are needed!**
- **Design of software is too difficult and expensive**
- **What's missing is a unified middleware or engineering approach**
- **configKIT approach can help**
- **Done:**
  - **way of module description**
  - **Selection algorithm**
- **ToDo:**
  - **Find better metrics for estimation of properties**
  - **Find a way to verify security and safety properties**
  - **Automatic integration**

Thank You

Questions?

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