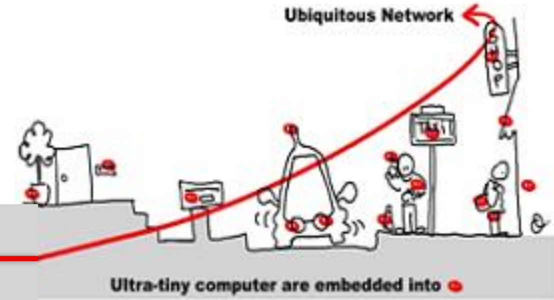

Self Adaptive Middleware for Ubiquituous Computing : Lecture 6

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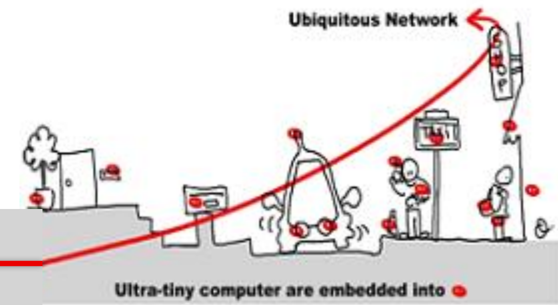
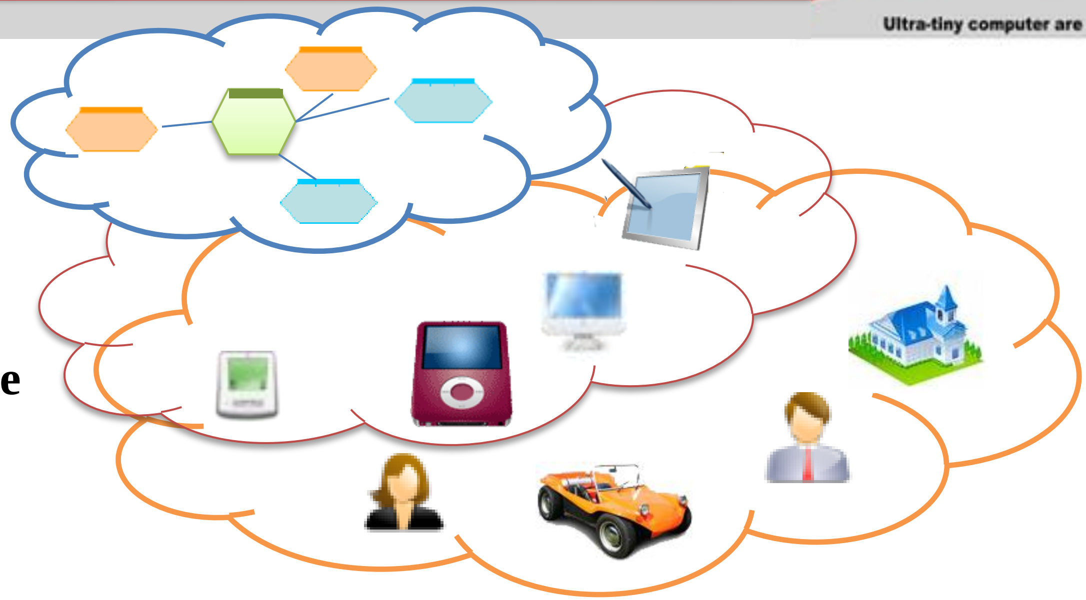
Main Ubiquitous Computing Characteristics



Software Applications

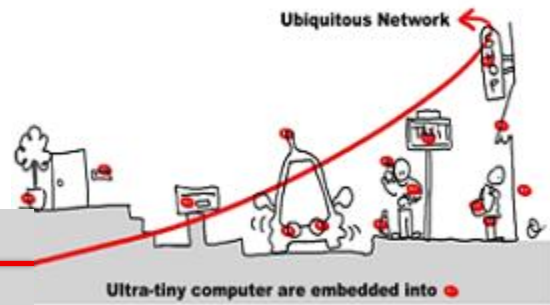
Software Infrastructure

Environment



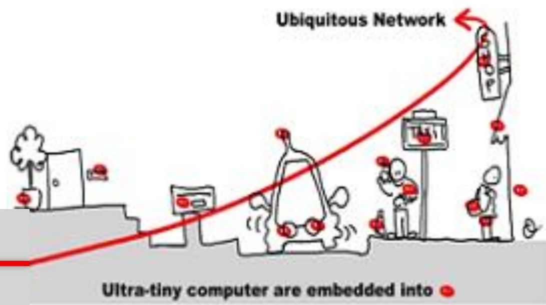
- Three main characteristics are :
  - Use embedded devices in a real environment
  - Deal with Multiple Heterogeneous Devices
  - Deal with Highly Dynamic variation at Runtime

Main Ubiquitous Computing Requirements

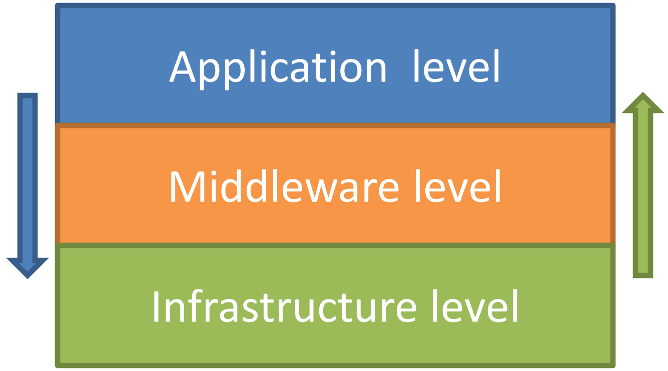


- Main requirements are :
  - Real Environment => Event based interaction from devices
  - Heterogeneous Devices => Discovery of new software entities and devices
  - Highly Dynamic at Runtime => Deal with dynamic appearance and disappearance of devices
  - Highly Dynamic at Runtime => Deal with dynamic composition (at runtime)
  - Highly Dynamic at Runtime => Deal with dynamic adaptation (self- adaptation)

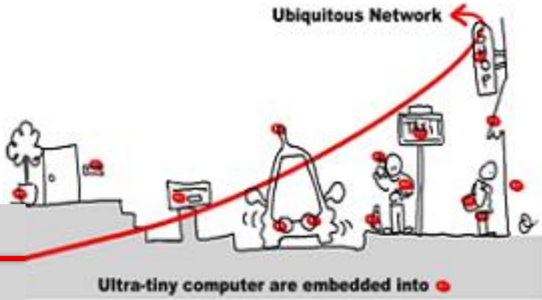
Challenge 1 : Real world interaction



- Ubiquitous Computing applications are continuously interacting with a real world, partly unknown at design time and, always changing at runtime in uncountable manner
- We witness to a kind of inversion in the classical software methodology where the software applications levels are much more stable and stationary than the software infrastructure level.

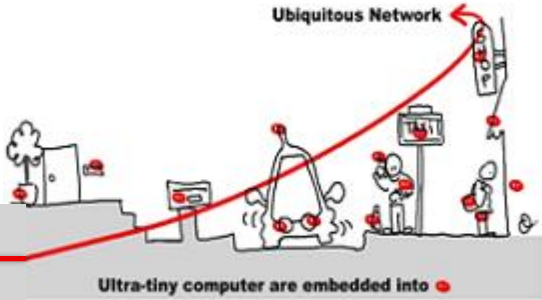


Challenge 2 : Multi-Domain Adaptation



- Ubiquitous Middleware must continuously adapt at runtime, application requirements to changing computing environment (due to mobility) in multiple domains :
  - HMI,
  - Power,
  - Network bandwidth,
  - Devices availability, …

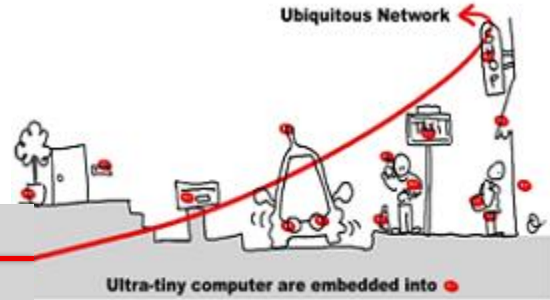
Challenge 3 : Reactive Adaptation



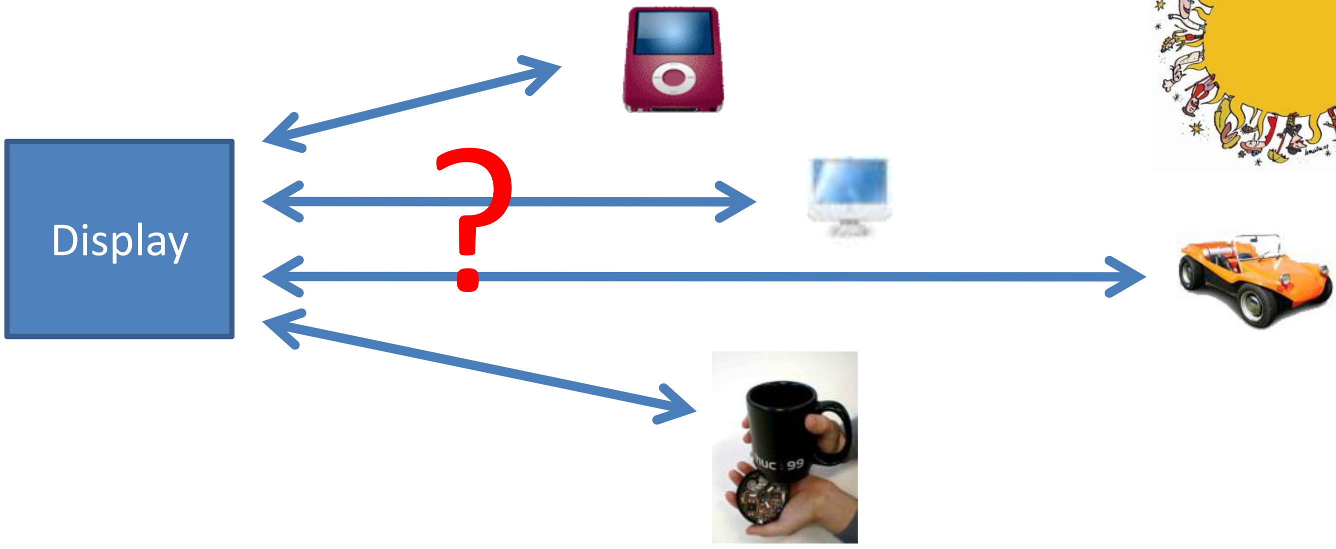
- Reactive adaptation is defined as the ability for the Ubiquitous applications to perceive the environment and adapt to changes in that environment in a timely fashion.

- Ubiquitous Middleware must provide reactive adaptation mecanism to changing operational environment.

Challenge 4 : Semantic Adaptation

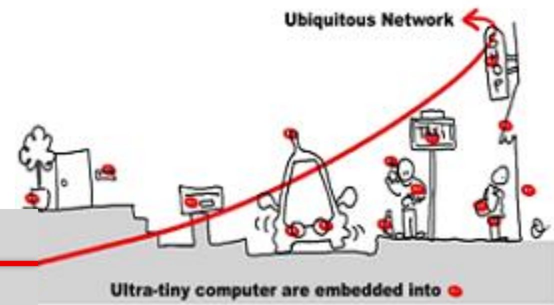


- Ubiquitous Middleware must match at run-time the current operational environment and application requirements.



Can match with ?

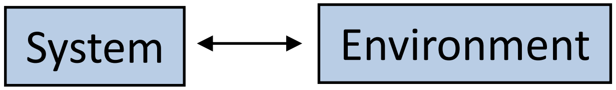
Self-adaptive System Definition



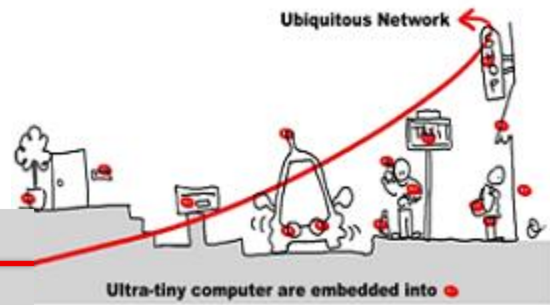
By self adaptive we mean systems and components that configure themselves and dynamically adapt to changing environments with minimal human participation.

Many systems have some degree of self-adaptiveness, but the abilities vary:

- static systems: parameter adaptation
- dynamic systems: compositional adaptation



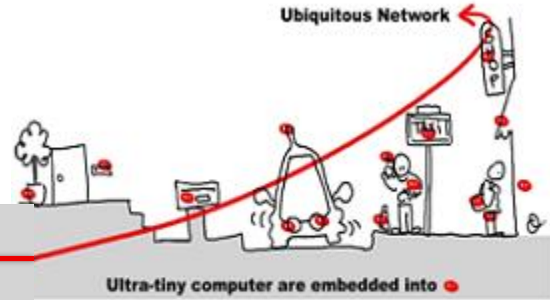
Adaptivity classes



- Parameter adaptation: changing values without changing components or algorithms.
- Compositional adaptation:
  - Structural – changing parts and part structure
  - Behavioral – changing behavior/types and algorithms

Another classification:

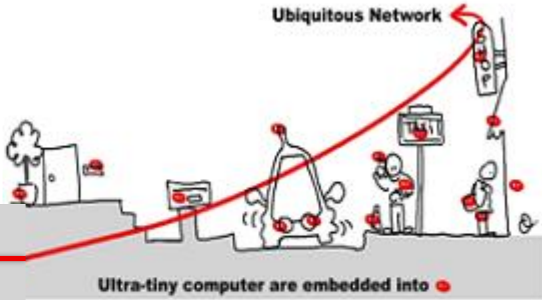
- Anticipated, semi anticipated and unanticipated adaptation.



Some Key Paradigms and Taxonomies for Adaptation

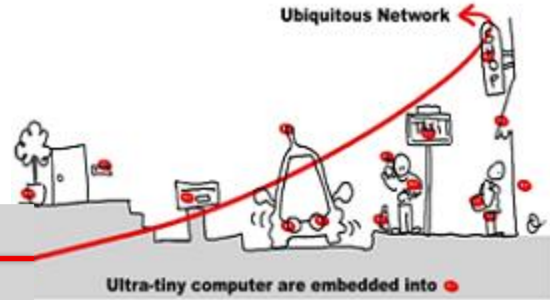
Computational Reflection
Component-Based Design
Aspect-Oriented Programming
Software Design Patterns

Middleware Paradigms for Adaptation



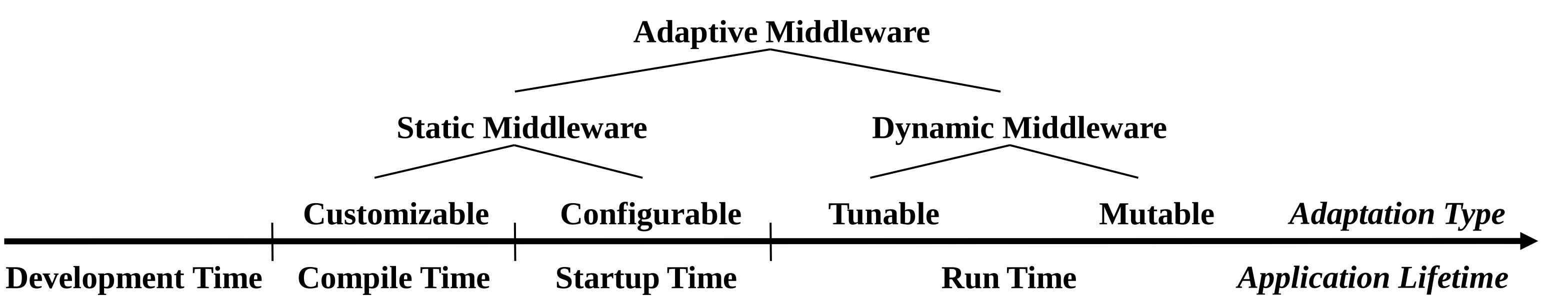
- Reconfiguration (Design Time) to Dynamic Adaptation (Runtime)
- Computational Reflection
- Policy-based adaptation
- Aspect-Oriented Programming

Reconfiguration (Design Time) towards Dynamic Adaptation (Runtime)

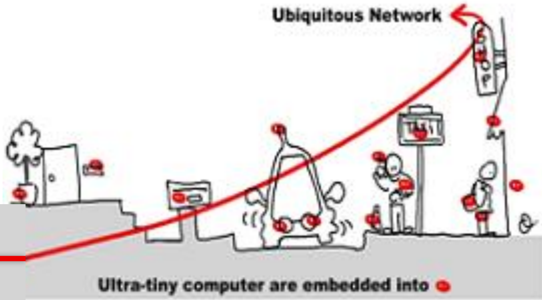


- Static Middleware
  - Customizable Middleware
    - Enables developers to compile (and link) customized versions of applications.
  - Configurable Middleware
    - Enables administrators to configure the middleware after compile time.

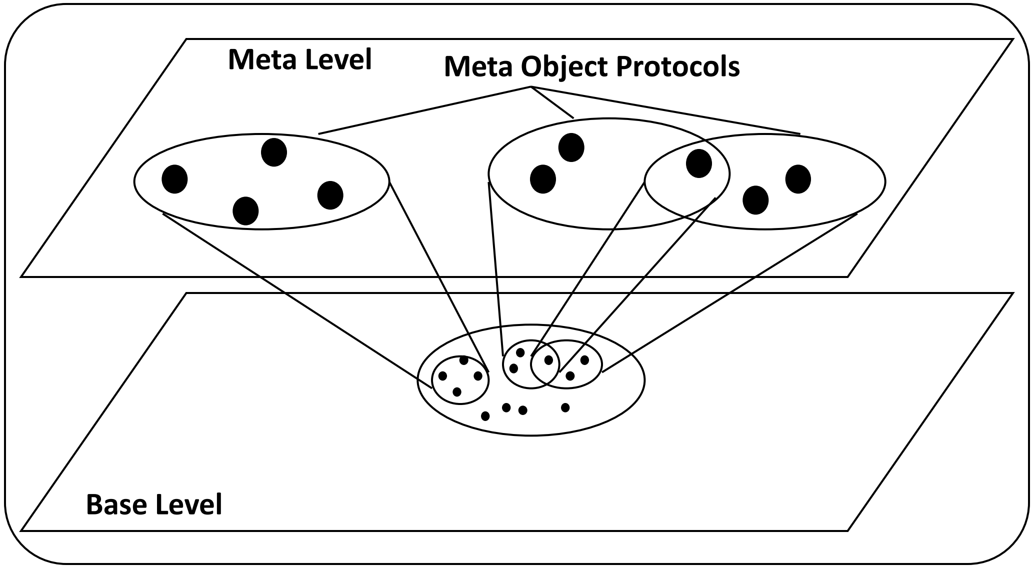
- Dynamic Middleware
  - Tunable Middleware
    - Enables administrators to fine-tune applications during run time.
  - Mutable Middleware
    - Enables administrators to dynamically adapt applications at run time.



Computational Reflection

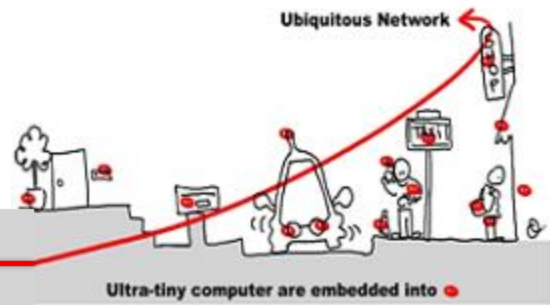


- The ability of a program to reason about, and possibly alter, its own behavior.
- Enables a system to “open up” its implementation details for such analysis without revealing the unnecessary parts or compromising portability.
- Terminology
  - Base-level
  - Meta-level
  - MOP
  - Casually connected
  - Per-ORB, per-class, per-object, and per-interface reflection



Relationship between meta-level and base-level objects.

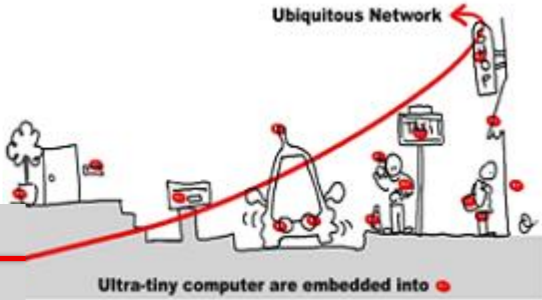
Policy-based adaptation



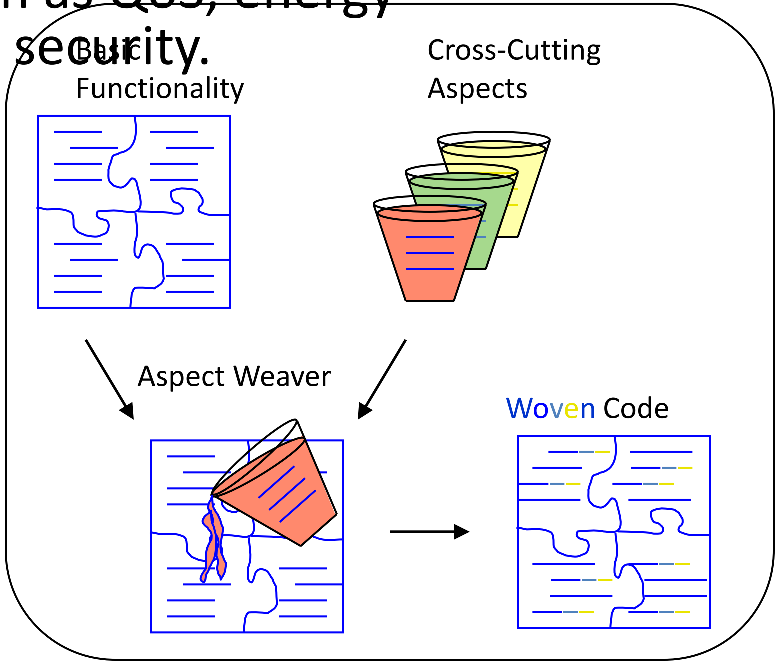
Policy Rules :		Middleware :
Particular conditions -> matching rules	→	selected script -> behavior modification

- Policy rules are often context based
- Example : ECA (Event-Condition-Action) rules
  - The event part specifies the context change that triggers the invocation of the rules
  - The condition part tests if this context change is satisfied
  - Which causes the description of the adaptation (action) to be carried out

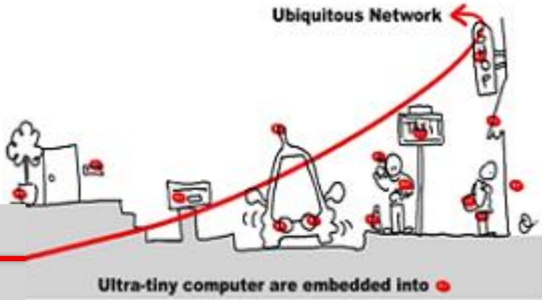
Aspect-Oriented Programming



- Complex programs are composed of different intervened cross-cutting concerns.
- Cross-cutting concerns:
  - Properties or areas of interest such as QoS, energy consumption, fault tolerance, and security.
- Terminology
  - Aspect
  - Basic Functionality
  - Aspect Language
  - Aspect Weaver
    - Static
    - Dynamic
  - Woven Code



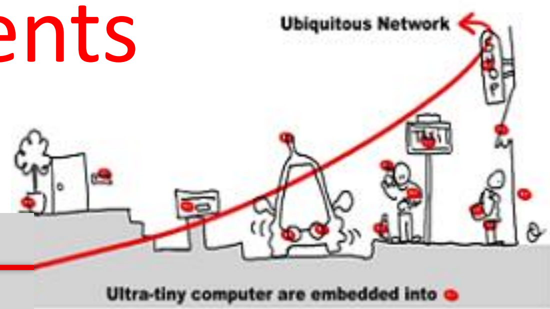
AOP in action.



Aspects of Assemblies Approach

For structural self-adaptation

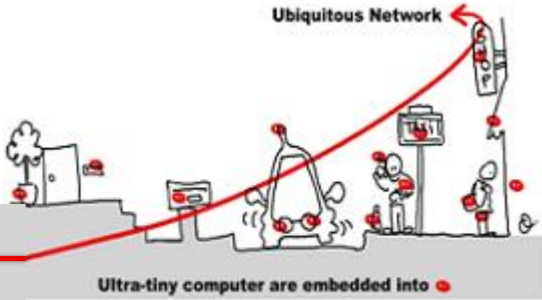
Ubiquitous Computing Requirements we address in WComp



- Hypothesis : Heterogeneity /appearance / Disappearance

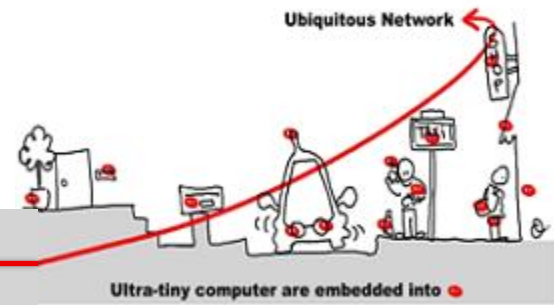
- Requirements :
  - Dynamic composition
  - Explicit distribution
  - Independant adaptations
  - Coherent adaptation
  - Timely adaptation
    - On demand
    - As quick as possible

Three levels for Dynamic Composition



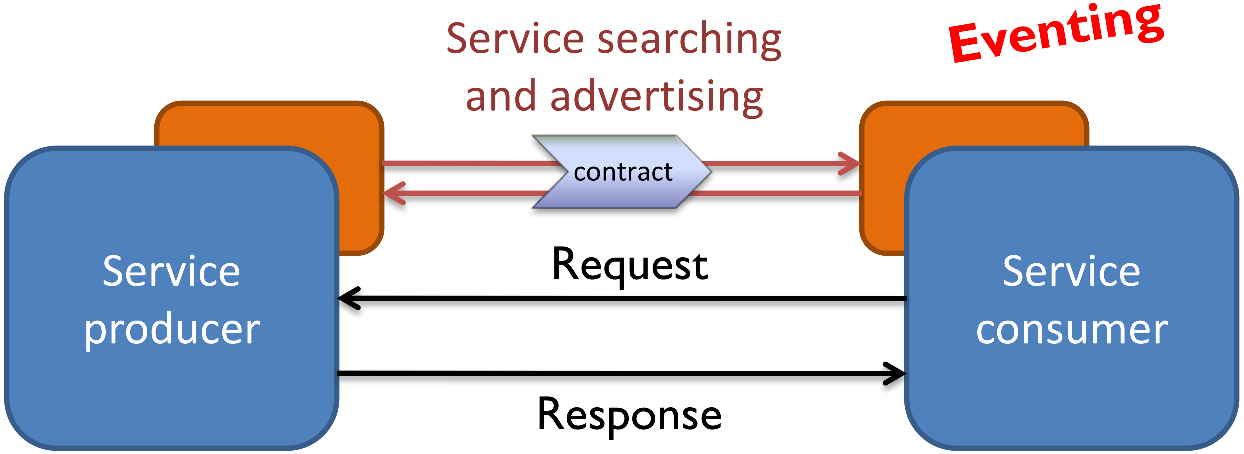
- Solution for the WComp Infrastructure : based on Web services for Device (previous lectures)
- Composition : WComp Local and Distributed composition (LCA and SLCA models), (previous lectures)
- Self Adaptation : WComp Reactive adaptation using Aspects of Assembly (AA) (this lecture)

Web Services for Devices Infrastructure

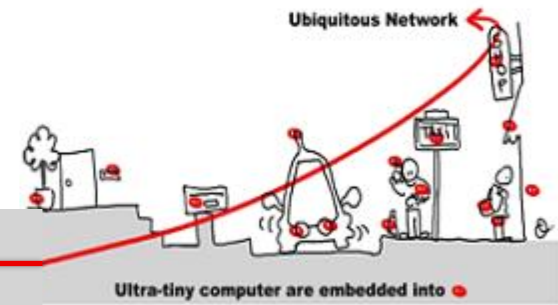


- Requirements for WComp Infrastructure
  - New ways of interacting: Eventing

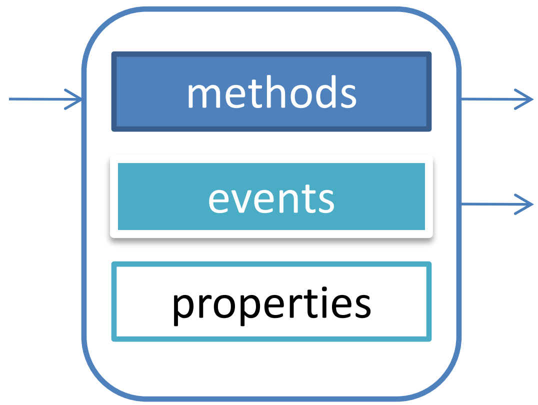
Decentralized and Contextual discovery
Managing Apperance and Disapperance
Eventing

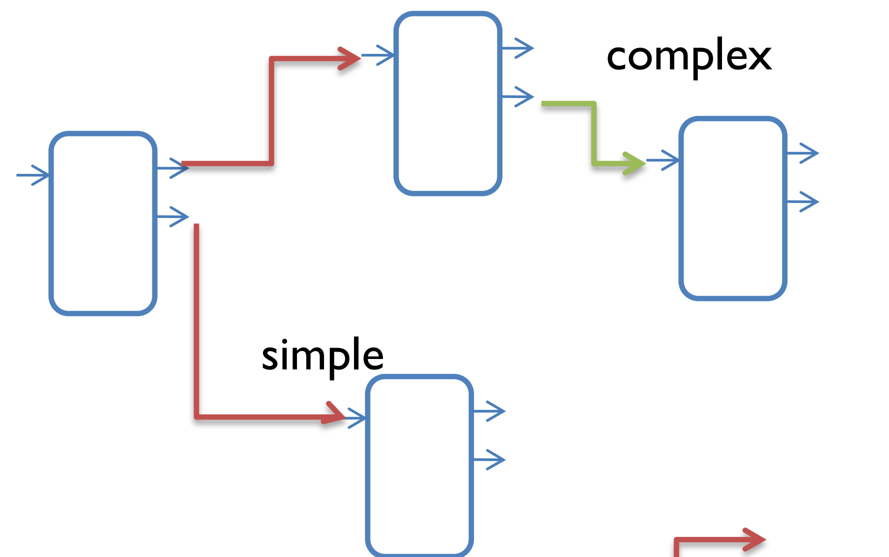


LCA model

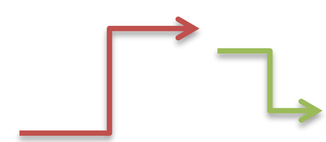


- LCA components

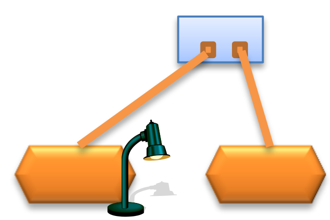




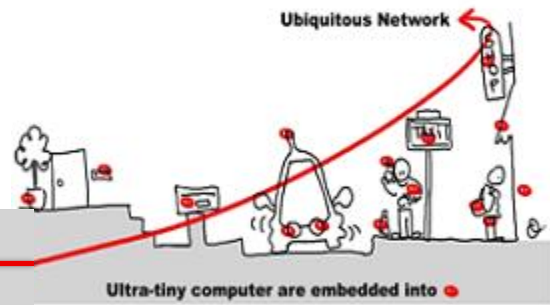
- Simple and complex Event based Connector



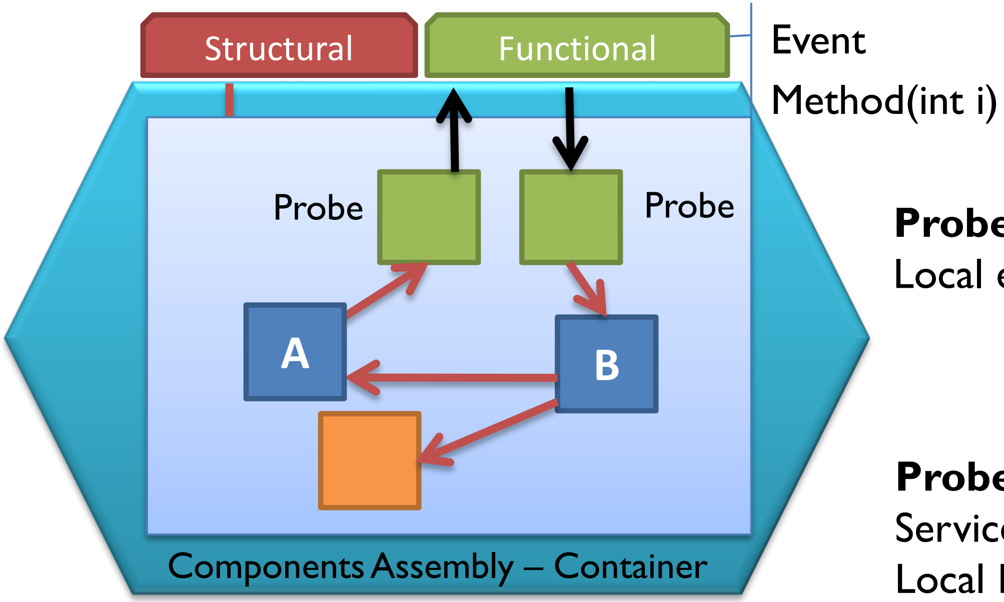
- Proxy Components



SLCA Model : Composite Service



- New components as Probe components



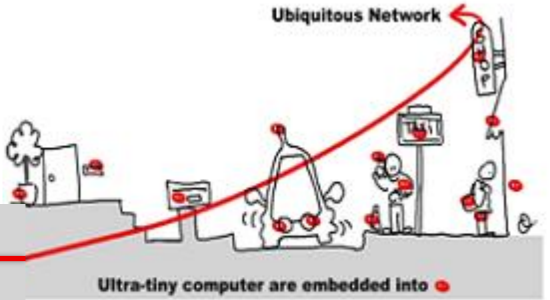
Composite Service

Probe emitter :
Local event → Service Event

Probe receiver :
Service Method Invocation → Local Event (Request)

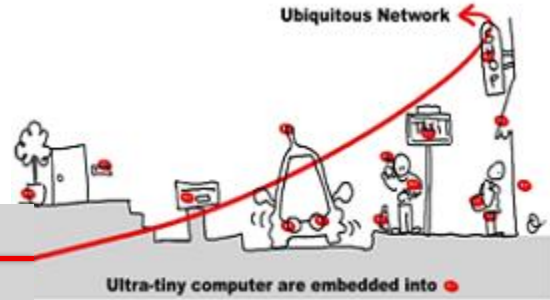
- Two interfaces : structural and functional

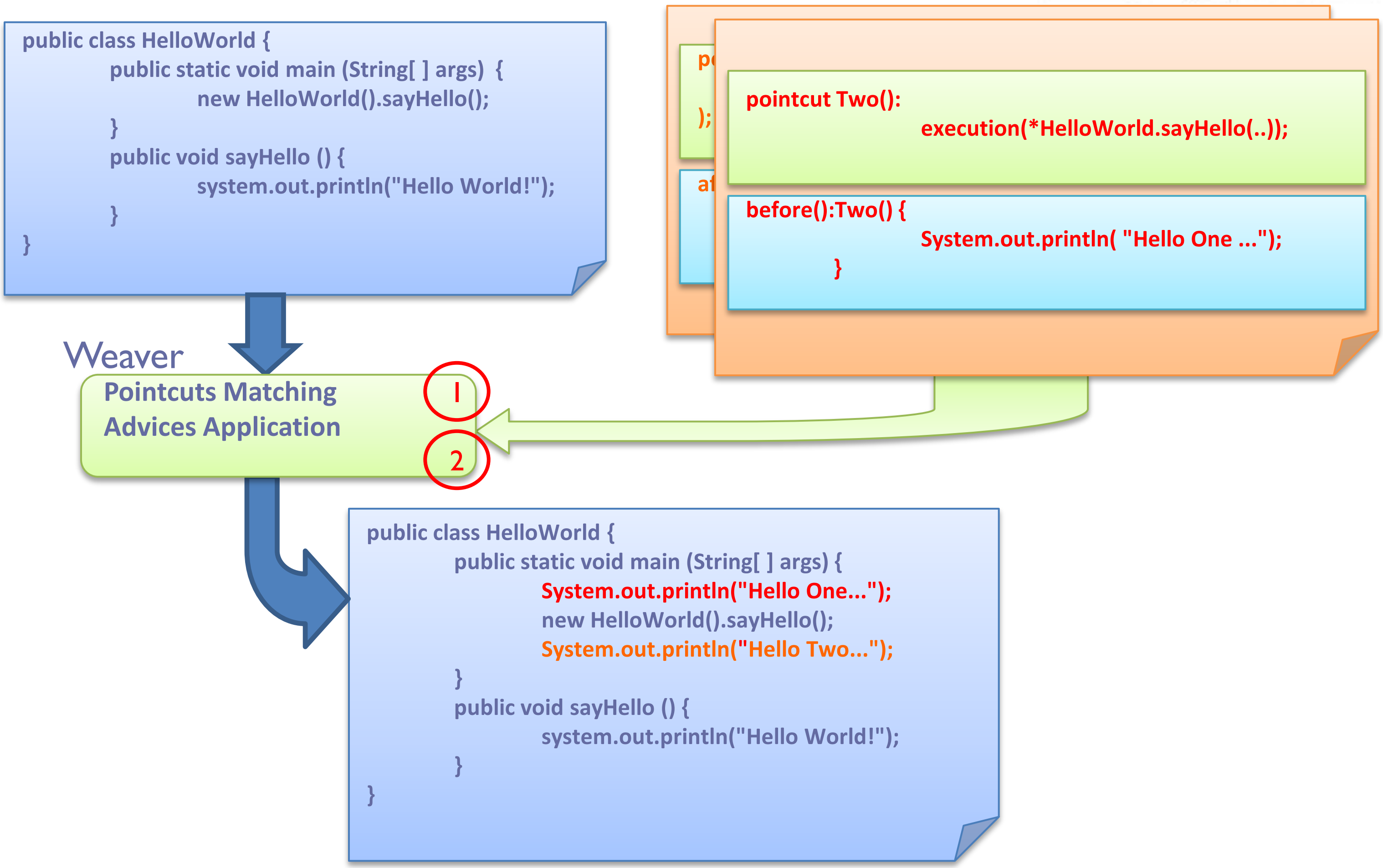
Aspect of Assembly Concept for self-adaptation



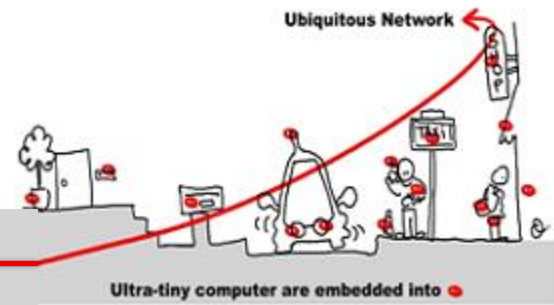
- From AOP Principles
- Aspect of Assembly Principles
- Complete AA Weaving Cycle
- Different kinds of conflict resolution

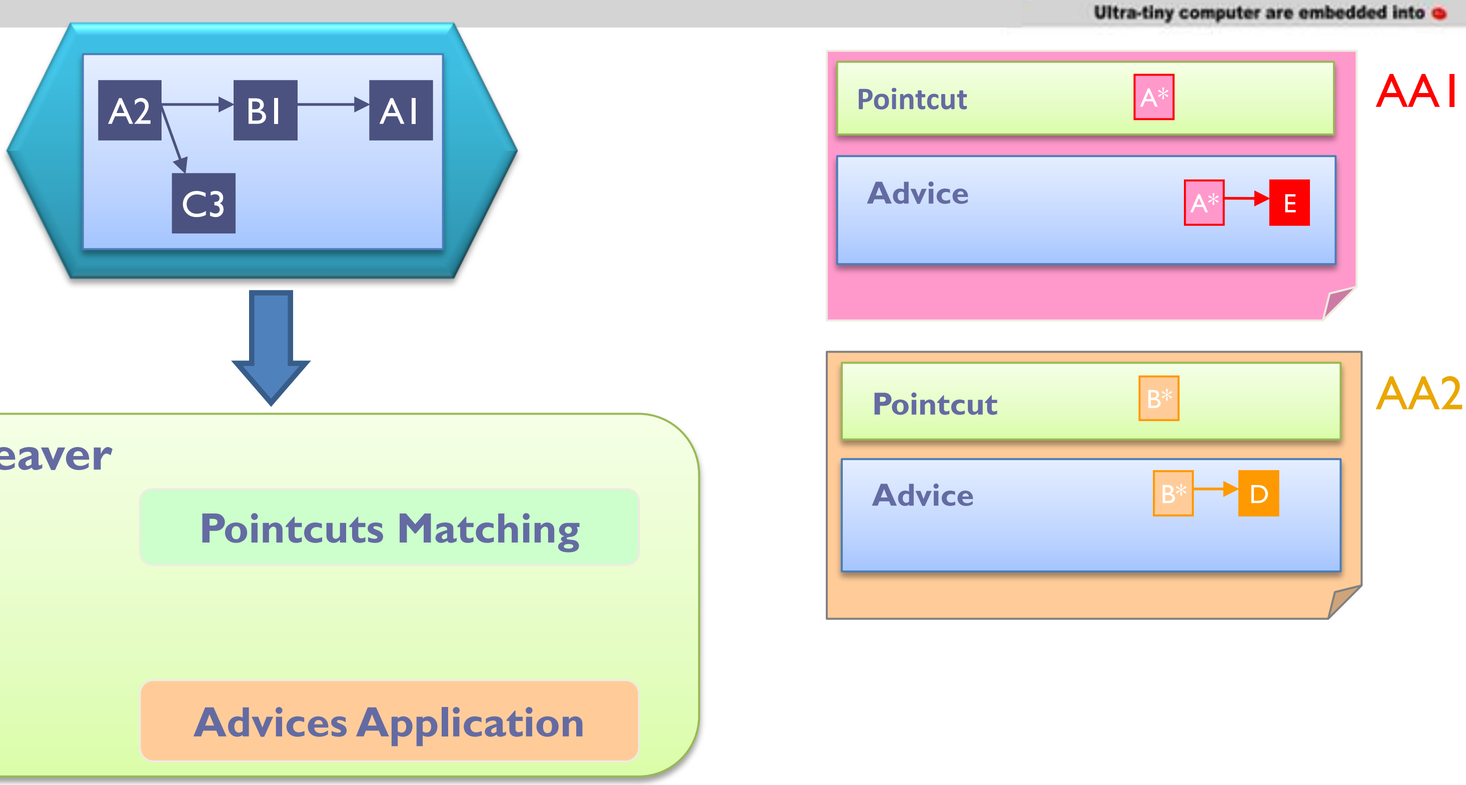
Reminder : AOP Principles





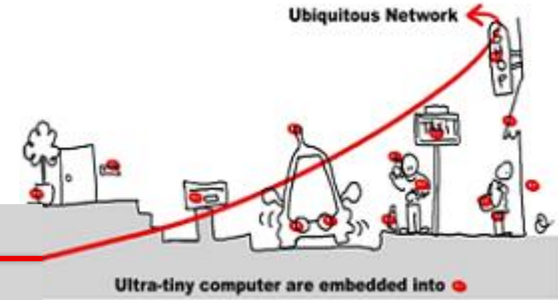
Aspect of Assembly Principles

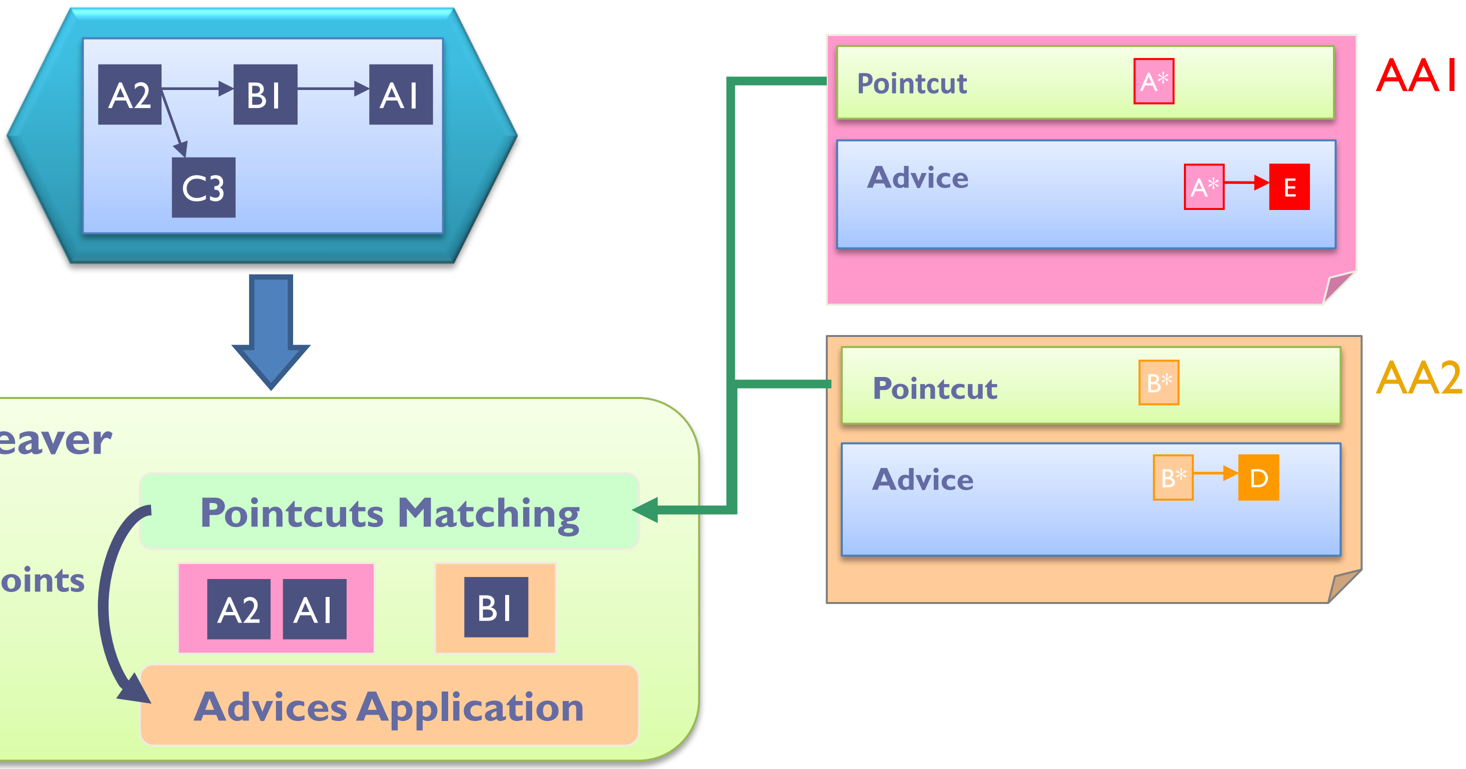




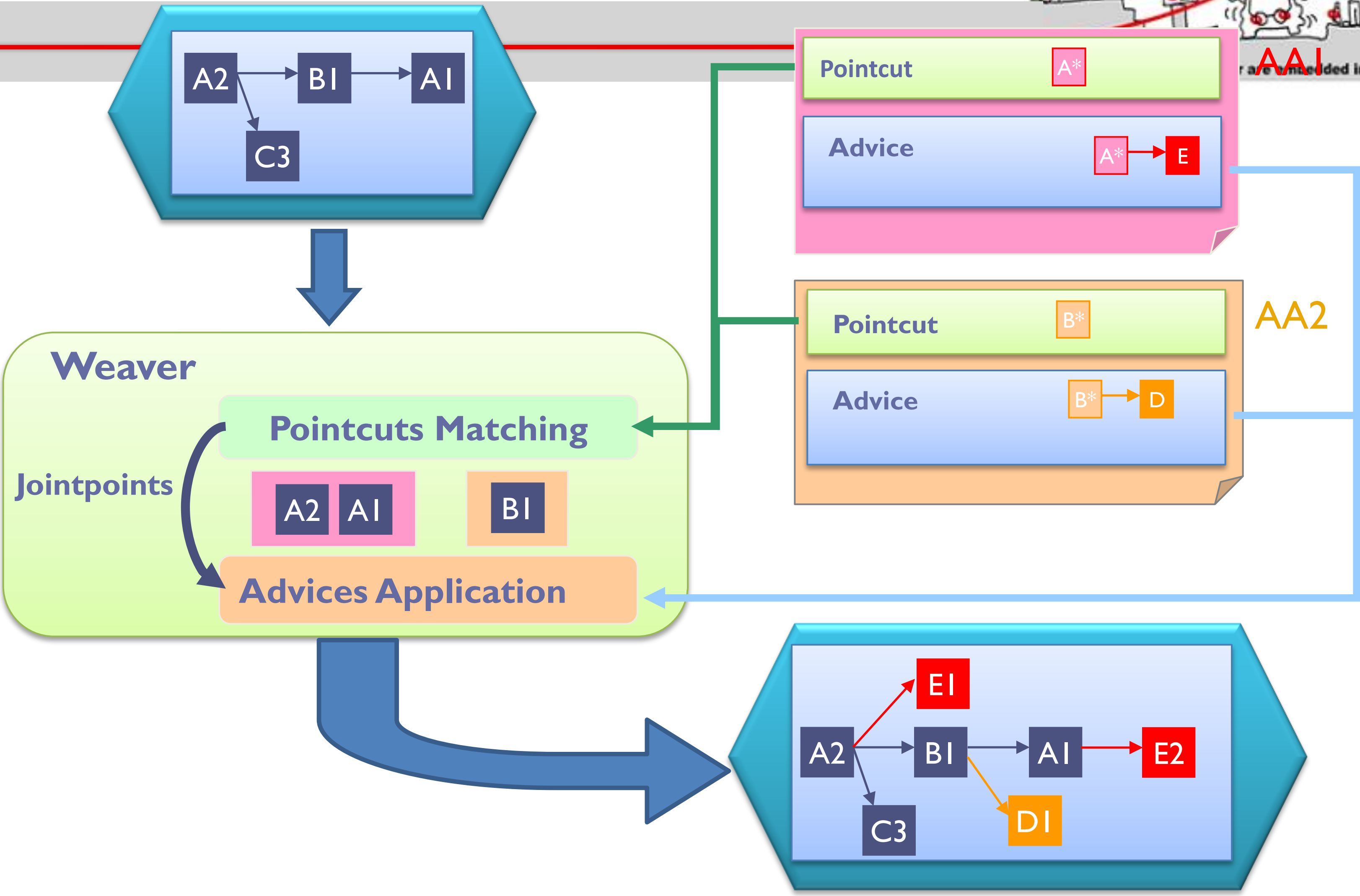
AOP inspired for Component based approach (like LCA)

Aspect of Assembly Principles

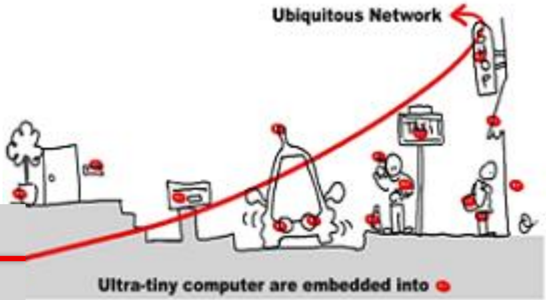


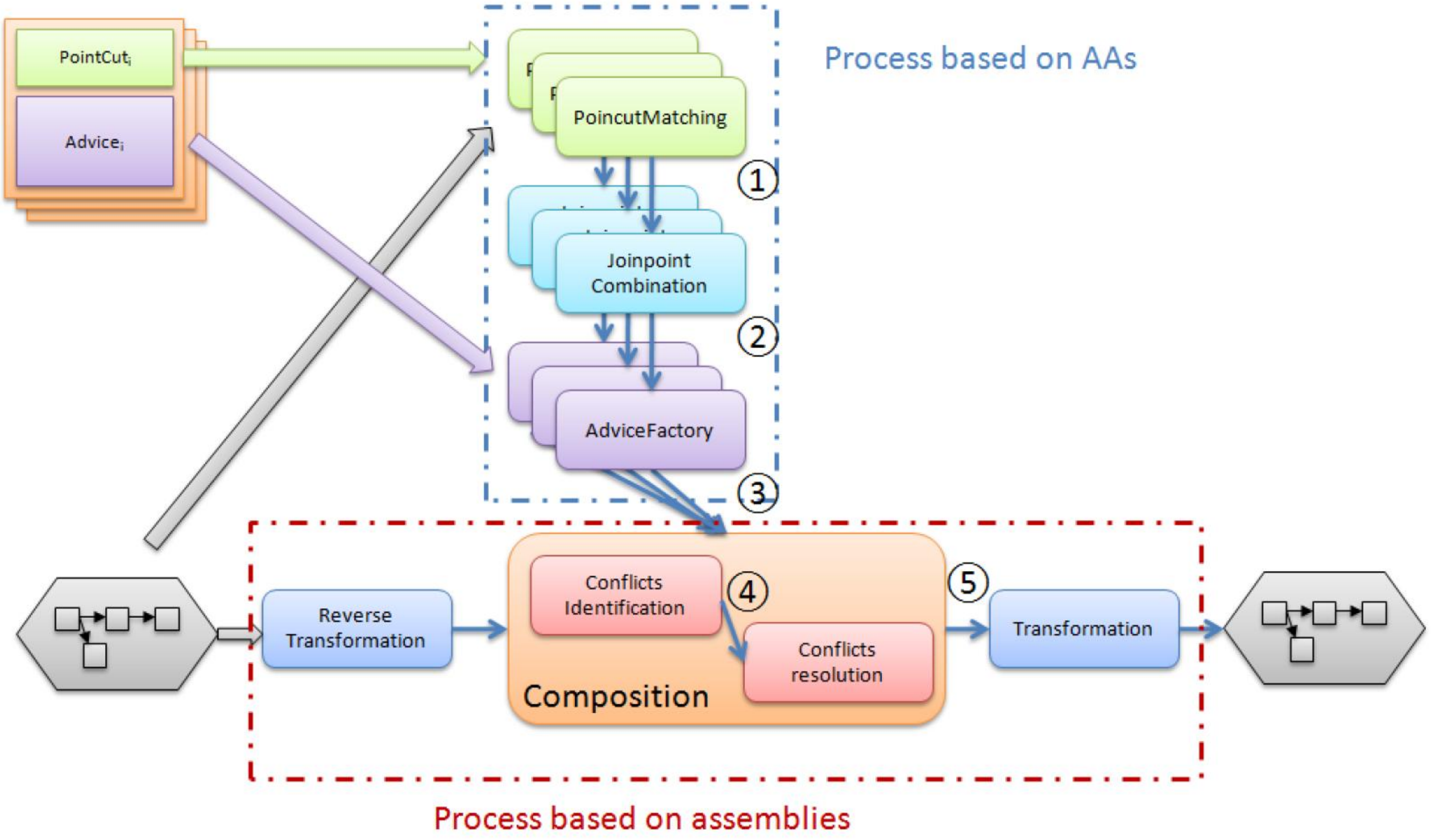


Aspect of Assembly Principles

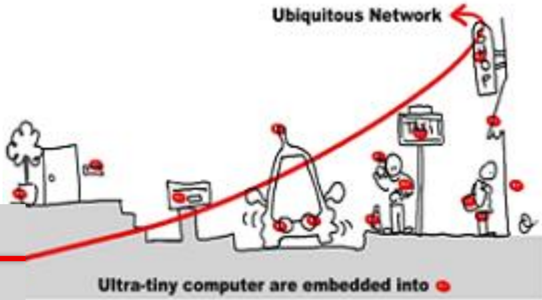


Complete AA Weaving Cycle

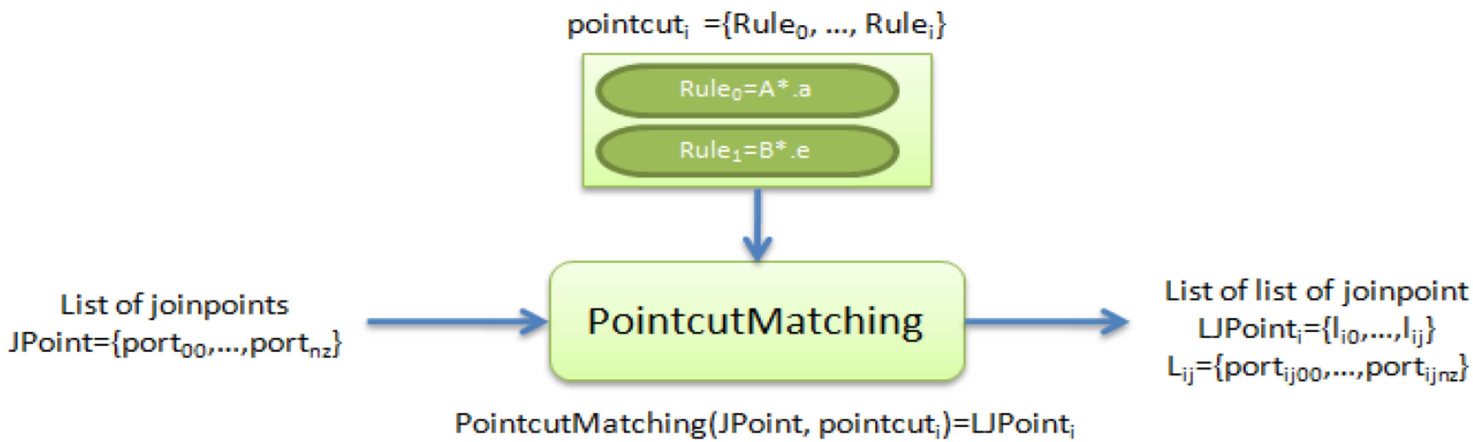




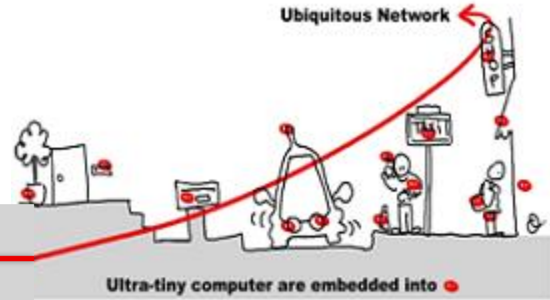
Pointcut Matching (1)

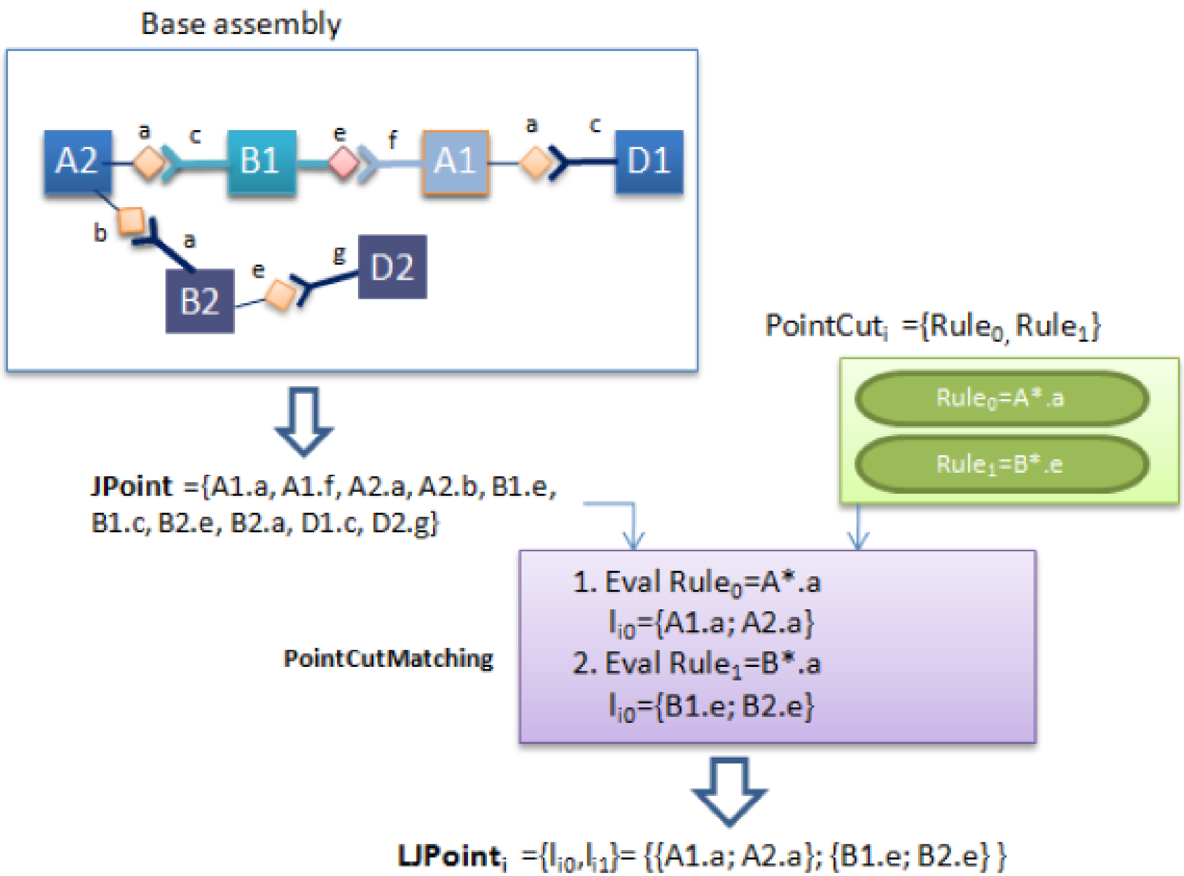


- Pointcut Matching aims to determine in the base assembly all areas where changes described in an AA can be applied.
- Indeed, it is a filter that takes as input all the ports present in the application.
- It is parametrized by the rules defined in the pointcut section of the AA.
- It produces some lists of joinpoints that satisfy each rule and more precisely, a list for each rule.



Pointcut Matching Example





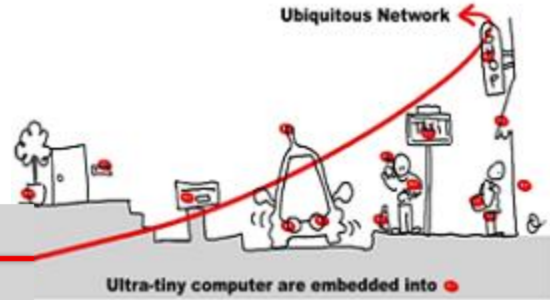
Pointcut Matching Algorithm

Algorithm 1 $PointcutMatching(JPoint, PointCut_i)$

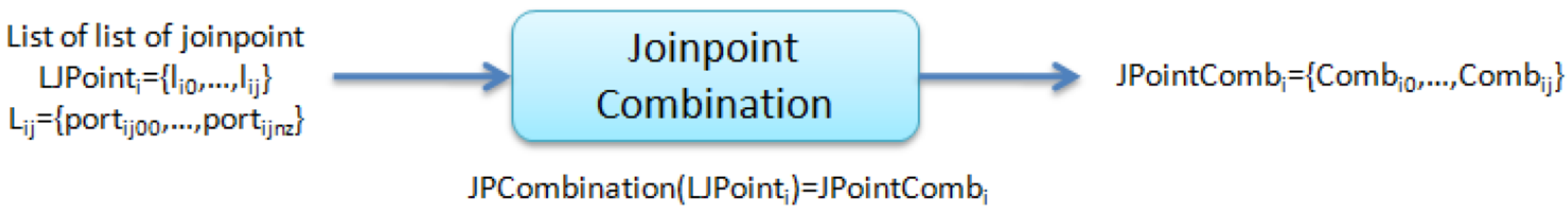
l_{ij} : a list of ports (joinpoint) where $l_{ij} = port_{ij00}, ..., port_{ijnz}$ and j is the number of list which is equal to the number of rules in $PointCut_i$
$LJPoint_i$: a set of joinpoint lists where $LJPoint_i = \{l_{io}, ..., l_{ij}\}$
$JPoint$: the set of ports from the base assembly $port_{00}, ..., port_{nz}$ y.

create $LJPoint_i$
for $s = 0$ to j **do**
    Add a new list l_{is} to $LJPoint_i$
    for $t = 0$ to card(JPoint) **do**
        if JPoint[t] satisfy the rule $Rule_{is}$ **then**
            Add JPoint[t] to the list l_{is}
        end if
    end for
end for

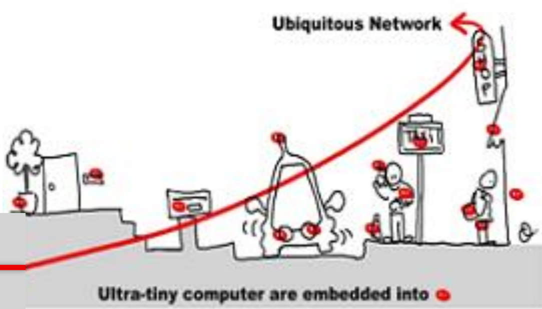
Jointpoint Combination (2)



- Joinpoint combination and filters
- Join Point Combination aims to combine joinpoints that satisfy the pointcut matching according to various policies in order to dene how and where will be duplicated the AA.
- Joinpoints lists created identify all ports that check pointcut rules, in fact a list for each rule. To be applied, advices require at least an element of each list : a combination.
- Thus, an advice can be applied as many times as there are combinations of joinpoints between these lists.



Jointpoint Combination Example



LJPoint$_i$ $=\{l_{i0}, l_{i1}\}$= {{A1.a; A2.b; A2.c}; {B1.e; B2.f}; {c1.g} }

⇩

Number of combination
Product=3*2*1=6

A1.a	A2.b	A2.c
B1.e	B2.f	
C1.g		

Number of list beginning with A1.a
Product/Card(LJPoint [0])=6/3=2

{ A1.a }{ A1.a } { A2.b }{ A2.b } { A2.c }{ A2.c }

Number of list beginning with A1.a and B1.e
Product/Card(LJPoint [1])=2/2=1

{ A1.a B1.e }{ A1.a B2.f } { A2.b B1.e }{ A2.b B2.f } { A2.c B1.e }{ A2.c B1.f }

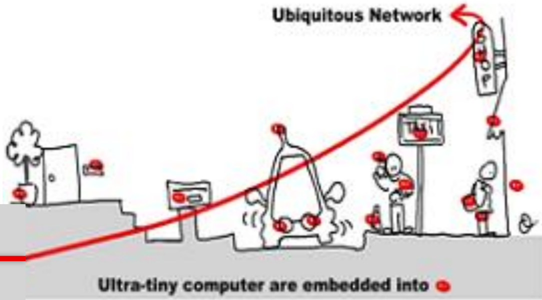
Number of list beginning with A1.a and B1.e and c1.g
Product/Card(LJPoint [2])=1/1=1

{ A1.a B1.e C1.g }{ A1.a B2.f C1.g } { A2.b B1.e C1.g }{ A2.b B2.f C1.g } { A2.c B1.e C1.g }{ A2.c B1.f C1.g }

⇩

JPointComb$_i$ $=\{Comb_{i0}, Comb_{i1}, Comb_{i2}, Comb_{i3}, Comb_{i4}, Comb_{i5}\}$=
{(A1.a,B1.e,C1.g); (A1.a,B2.f,C1.g); (A2.b,B1.e,C1.g); (A2.b,B2.f,C1.g)
(A2.c,B1.e,C1.g);(A2.c,B1.f,C1.g)}

Jointpoint Combination Algorithm

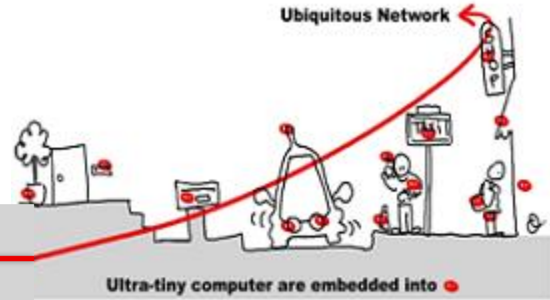


Algorithm 2 JPCombination($LJPoint$)

```
ACombination: list of joinpoint
Product: Integer : number of possible combination
mult : Integer : number of combination using the joinpoint
lcomb: list of combination

mult=1;
create JPointComb
for i = 0 to card(LJPoint) do
   Create lcomb
   ACombination.Clean
   product = product/(card(LJPoint[i]) − 1)
   for j = 1 to card(LJPoint[i]) do
      for k = 0 to product do
         ACombination.Add(LJPoint[i][j])
      end for
   end for
   for j = 1 to mult do
      lcomb.Add(ACombination)
   end for
   JPointComb[i]= lcomb
   mult = mult × (card(LJPoint[i]) − 1)
end for
return JPointComb
```

Filter Algorithm



- To Poincut Matching and combination mechanisms may be associated some filters.
- The filter associated to the pointcut matching can withdraw some identified joinpoints.

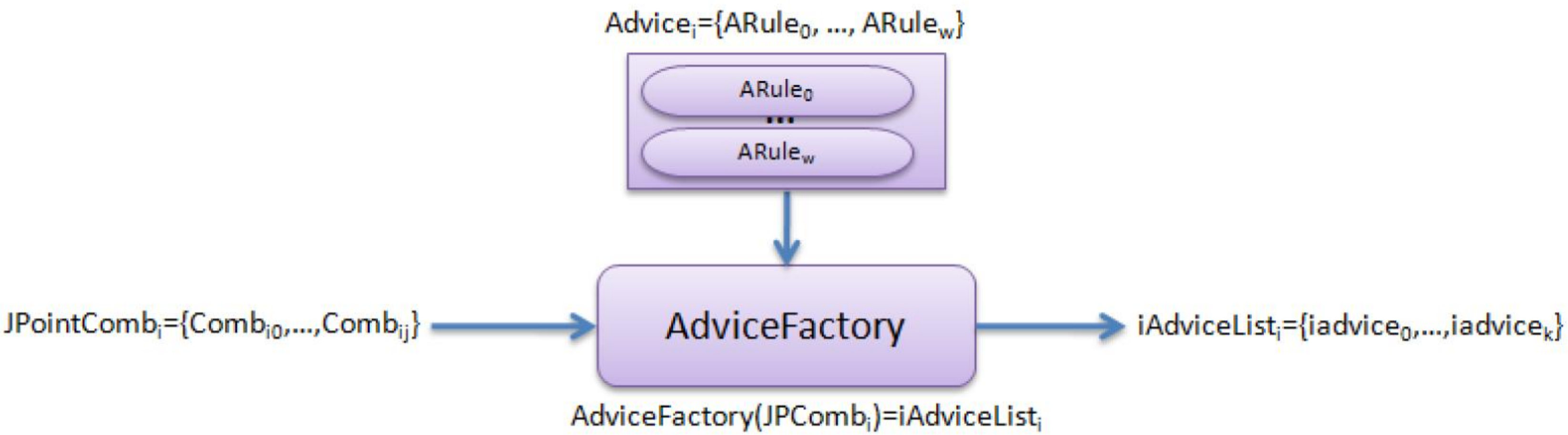
Algorithm 3 Filter

j : number of combination

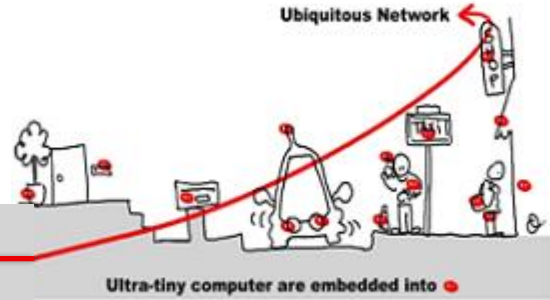
for $s = 0$ to j **do**
  for $t = 0$ to $card(LJPoint_i[j])$ **do**
    if filtre($l_{is}[t]$) **then**
      $l_{is}.remove(t)$
    end if
  end for
end for

Advice Factory (3)

- AdviceFactory aims to build, from the list of joinpoint combination, instances of advice.
- Thus it create as many instances of advice as possible according to the list of combinations.
- It consist in replacing variables from advice rules with the joinpoint from each combinations.



Advice Factory Algorithm



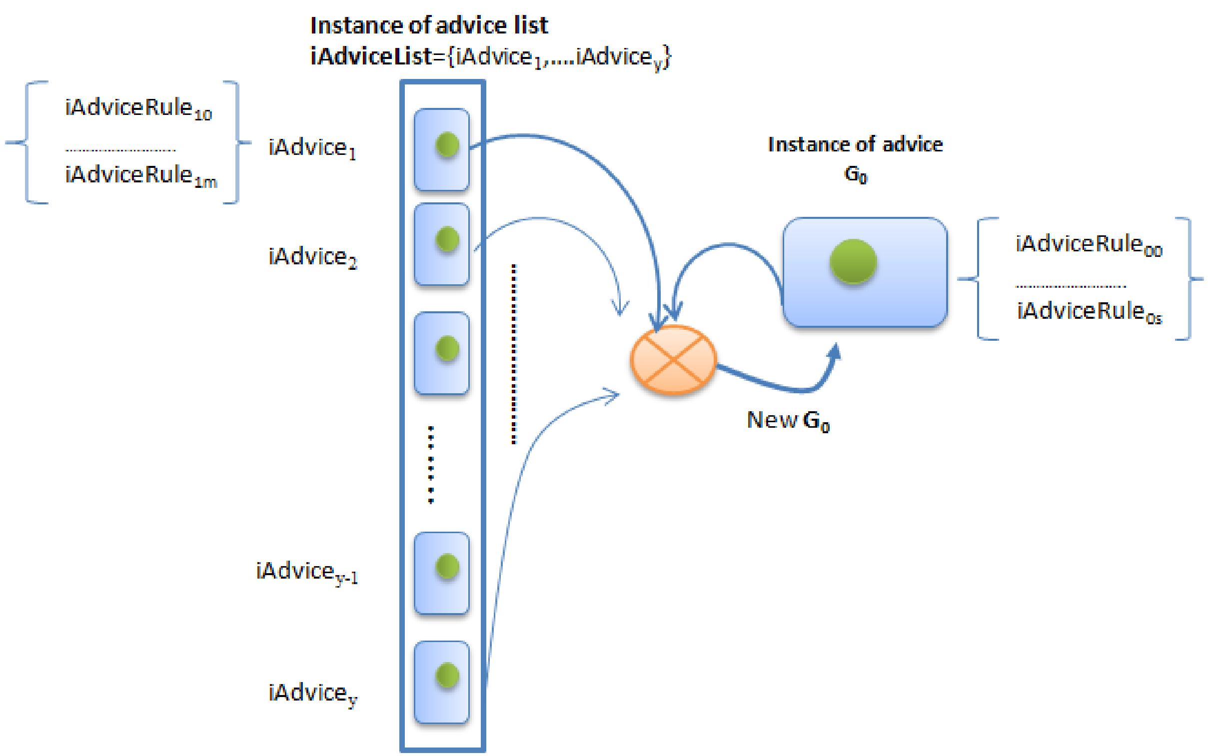
Algorithm 4 AdviceFactory($JPointComb_i$)

k : number of combination
w : number of advice rules

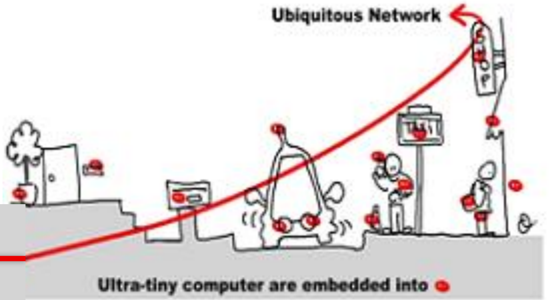
for $s = 0$ to k **do**
  for $t = 0$ to w **do**
    Replace variable from $ARule[t]$ using $JPointComb[s]$
  end for
end for

Conflict Identification (4)

- Superimposing component assemblies is a mechanism that builds a unique assembly from several intermediates component assemblies (and thus instances of advices).



Superimposition Algorithm

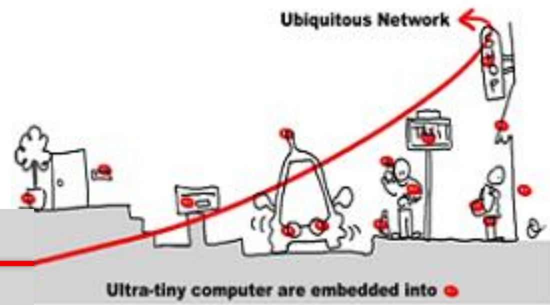


Algorithm 5 Superimpose(iAdviceList)

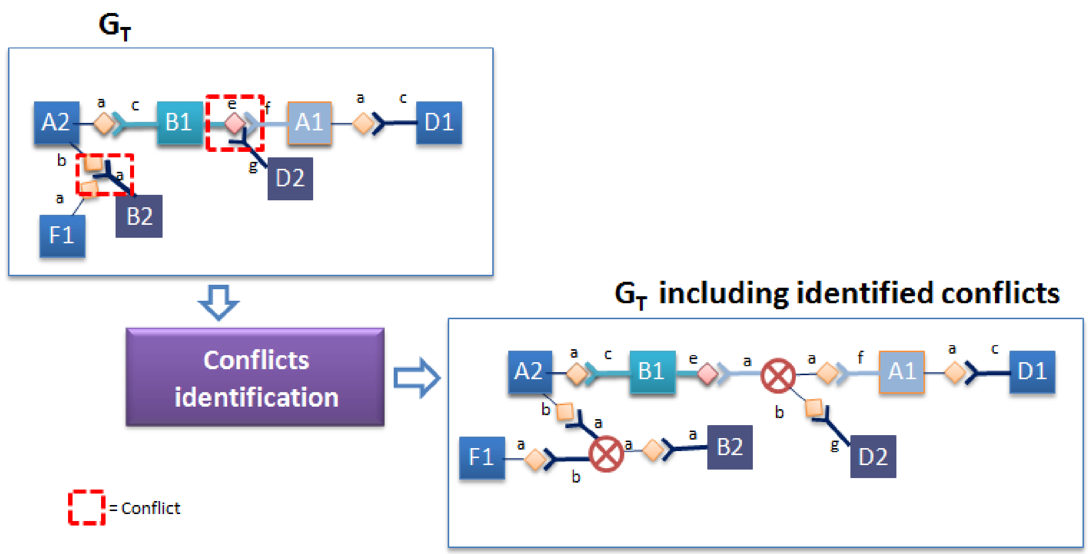
y : number of instance of advice

for $d = 0$ to y **do**
  for $t = 0$ to $card(iAdvise_d)$ **do**
    if $iAdvise_d[t] NotInG_0$ **then**
      Add $iAdvise_d[t]$ to G_0
    end if
  end for
end for

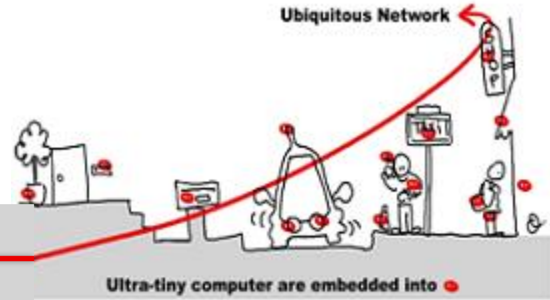
Conflict Resolution (5)



- Conflict resolution Conflict resolution aims to solve conflicts occurring when several instances of advices are woven on the same joinpoint (shared joinpoints)



Conflict Resolution Algorithm

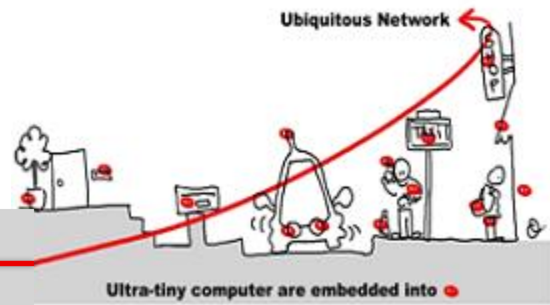


- Depends on the merge strategy
- Then depends on the Merge function

Algorithm 6 ConflictResolution(iAdvice)

for $s = 0$ to $card(List\otimes)$ **do**
    $Merge(List \otimes [s])$
end for

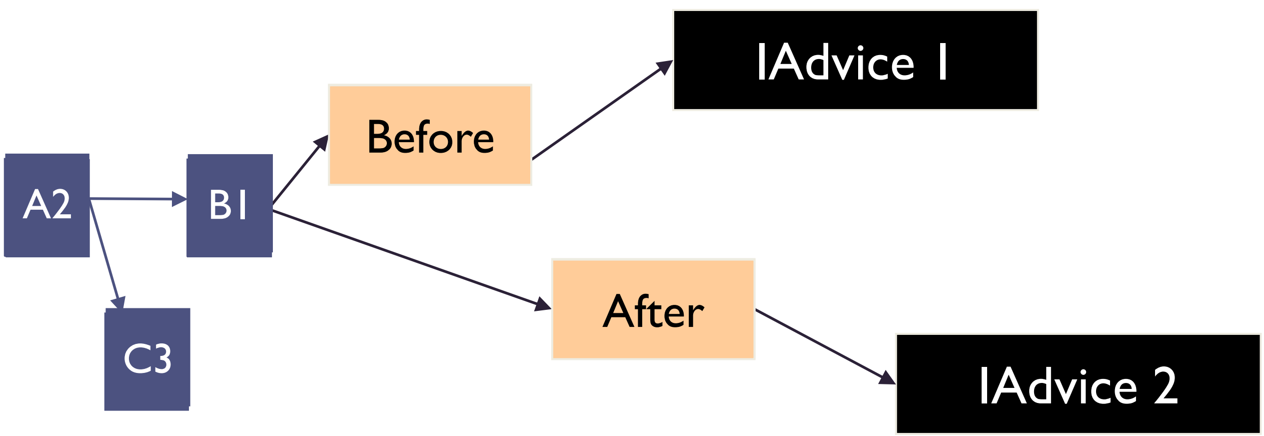
Different kinds of Conflicts Resolution



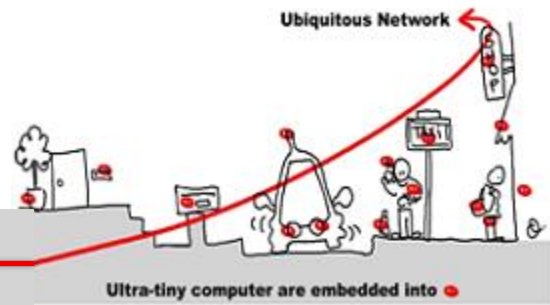
- External resolution for conflicts
- Internal resolution for conflicts (merge)
  - Example of language to describe advice : ISL4WComp
  - ISL4WComp operators merging matrix
  - Merging logic and its properties

External Composition

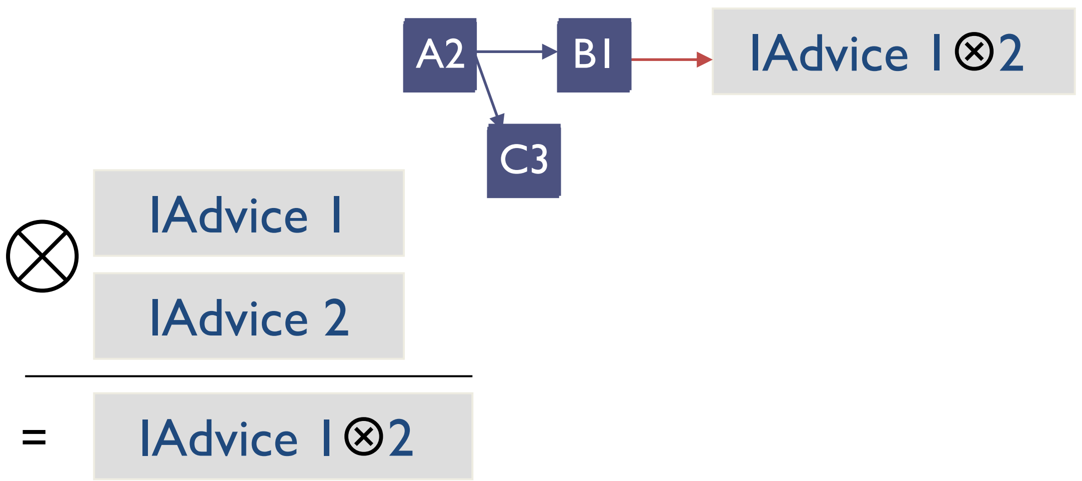
- I-Advices are « blackbox »
- I-Advices are scheduled
- Before, After, Around …



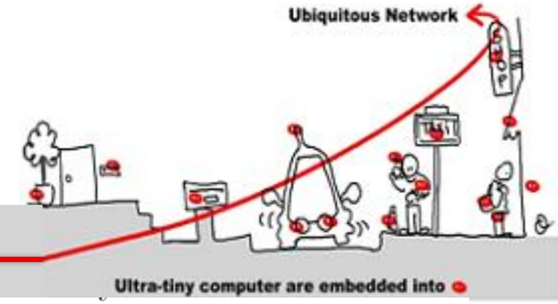
Internal Composition with Merge



- I-Advice are « whitebox »
- Conflicted I-Advices can be merged according to a specific logic and its properties (ex. ISL, ISL4WComp, BSL …)



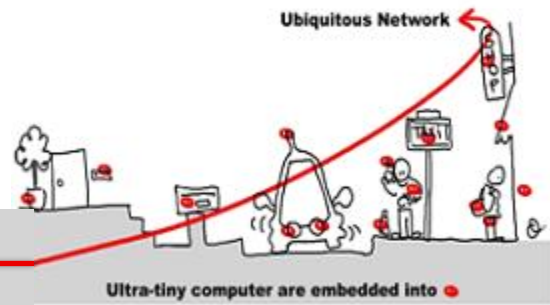
Example of language to describe advice : ISL4WComp



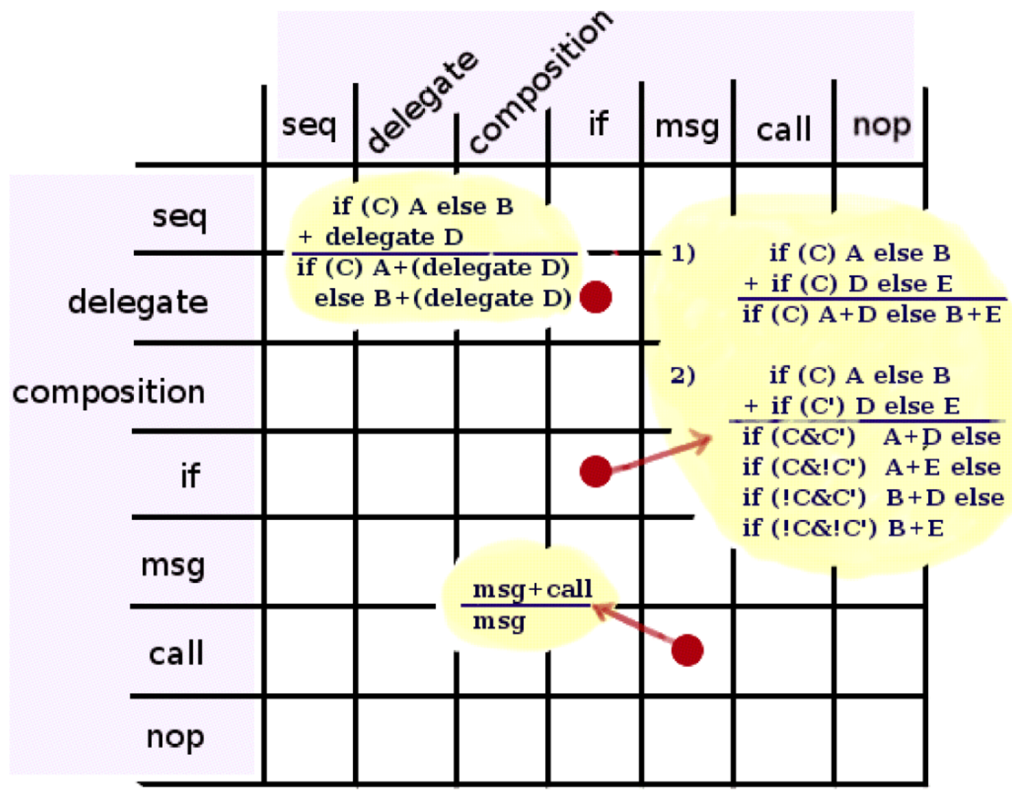
- Operators are :
  - ; (seq)
  - || (par)
  - If / else
  - Nop
  - Call
  - delegate

	Keywords / Operators	Description
port types	*comp.port*	'.' is to separate the name of an instance of component from the name of a port. It describes a provided port.
	comp.^ port	'^ ' at the beginning of a port name describes a required port.
Rules for structural adaptations	*comp : type*	To create a black-box component
	comp : type (prop = val, ...)	To create a black-box component and to initialize properties
	required_port → (required_port)	To create a link between two ports. The keyword → separates the right part of the rule from its left part
	provided_port → (required_port)	To rewrite an existing link by changing the destination port
Operators (symmetry property, conflicts resolution)	... ; ...	Describes the sequence
	... || ...	To describe that there is no order (parallelism)
	`if (condition) {...} else {...}`	`condition` is evaluated by a black-box component
	`nop`	Nothing to do
	`call`	Allow to reuse the left part of a rule in a rewriting rule
	`delegate`	Allow to specify that an interaction is unique in case of conflict

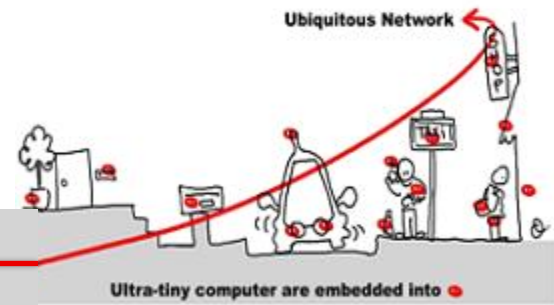
ISL4WComp Operators Merging Matrix



- Merging logic is based on rules to merge semantic trees of the advices
- Each rule gives the result of merging of one operator with another



Merging Logic and its Properties

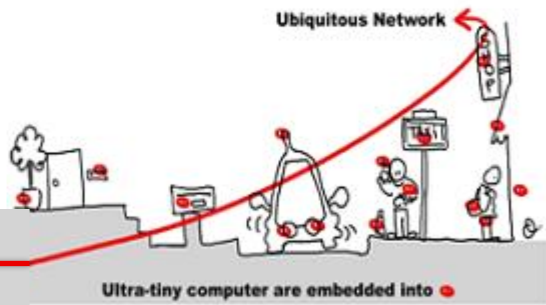


- Example of prooved properties for a composition / merging logic :

Commutativity : $AA0 \otimes AA1 = AA0 \otimes AA1$
Associativity : $(AA0 \otimes AA1) \otimes AA2 = AA0 \otimes (AA1 \otimes AA2)$
Idempotence : $AA0 \otimes AA0 = AA0$

- Weaving mecanism becomes « Symmetric »
- It can apply a set of AA without caring of their order.

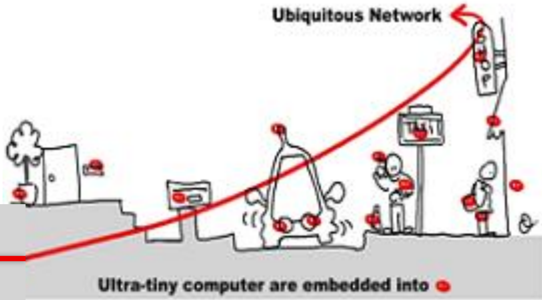
Details on AA temporal Validation (response time)

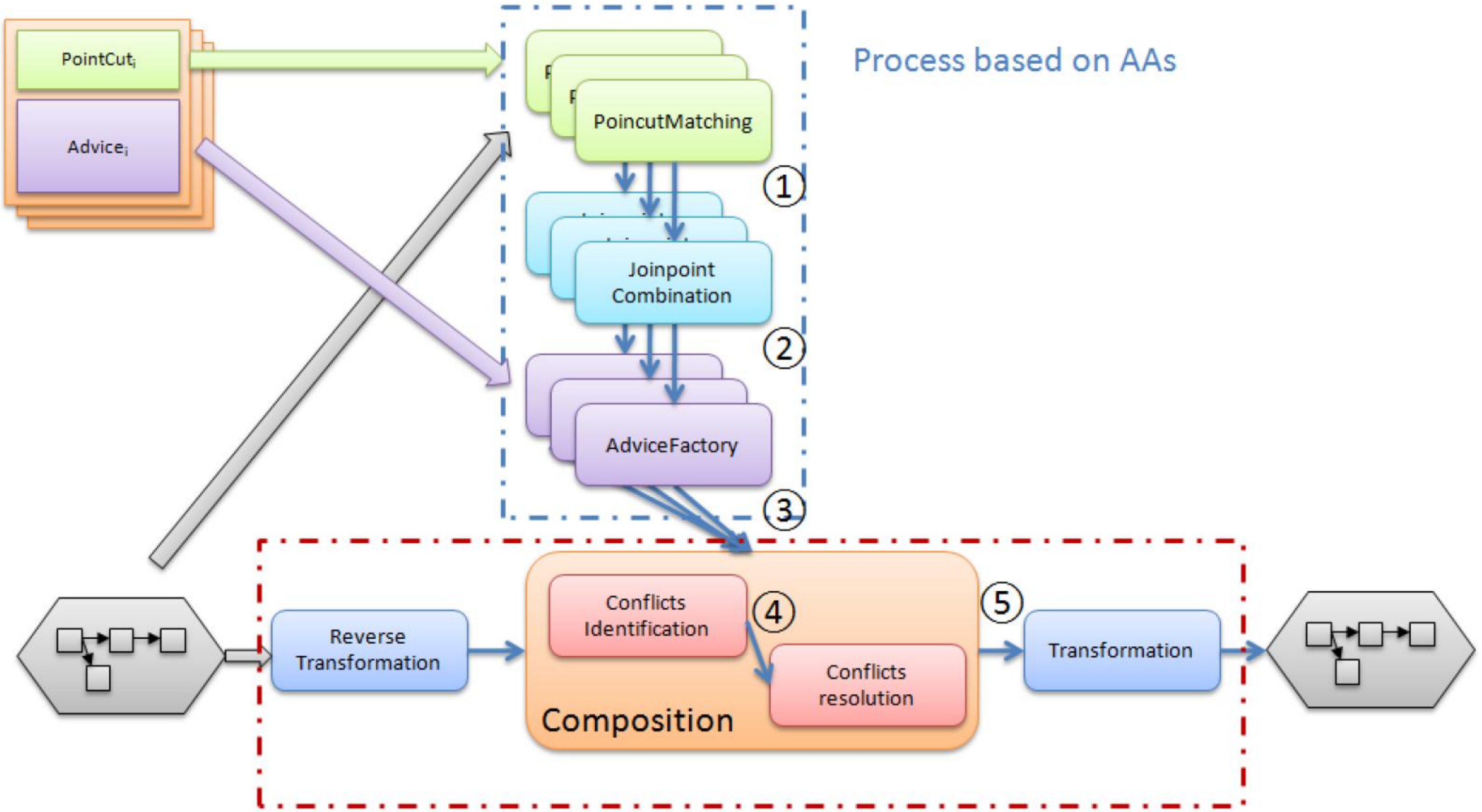


- To response in a timely fashion we need to garantee a minimum response time

- To study the response time of the overall adaptation process based on AA, we need to study :
  - Each algorithm and its complexity
  - Temporal model of the response time and the identification of its parameters

Complete AA Weaving Cycle





Pointcut Matching (1)

A : duration of the PointcutMatching process

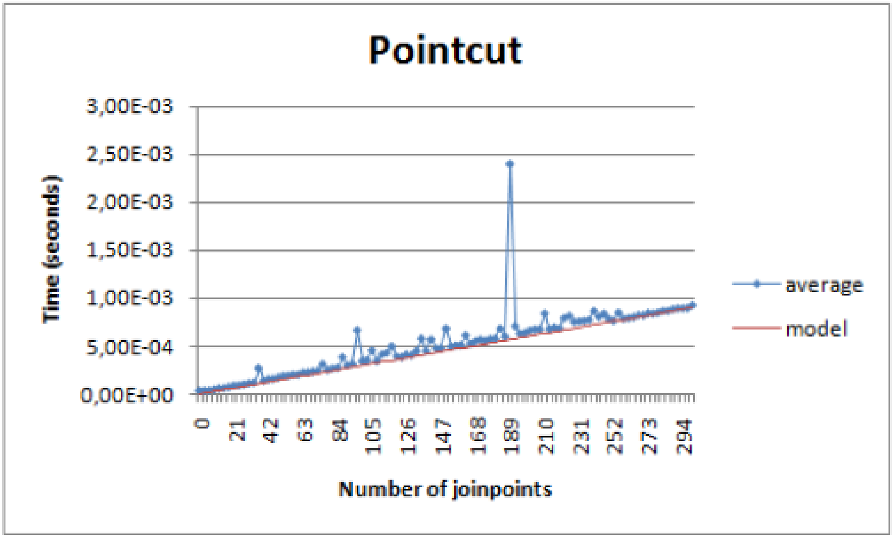
$a1; a2$: model parameters

c : number of ports into the base assembly

i : number of AA

j : number of rules in the pointcut section of an AA

$$A = a1 \times \sum_{k=1}^{i} (j.c) + a2$$



Joinpoint Combination (2)

C : Duration of the joinpoint combination process

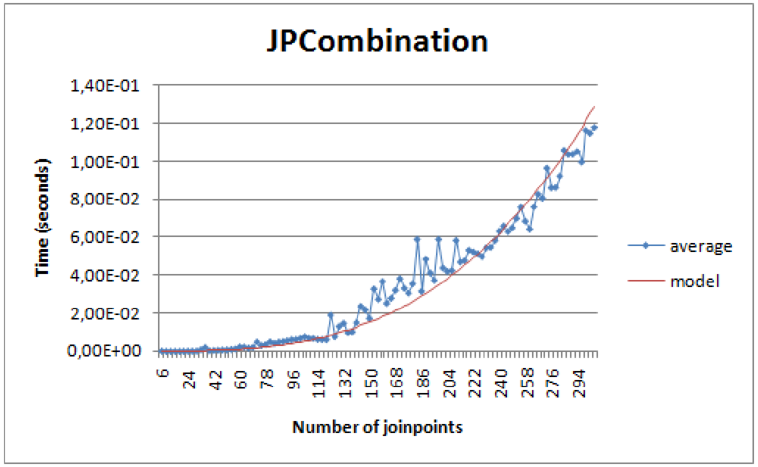
$a1; a2$: model parameters

$JPoint$: the set of joinpoints

i : number of AA

j : number of rules in the pointcut section of an AA

$$C = a1 \times \sum_{k=1}^{i} (card(JPoint)^{j}) + a2$$



Advice Factory (3)

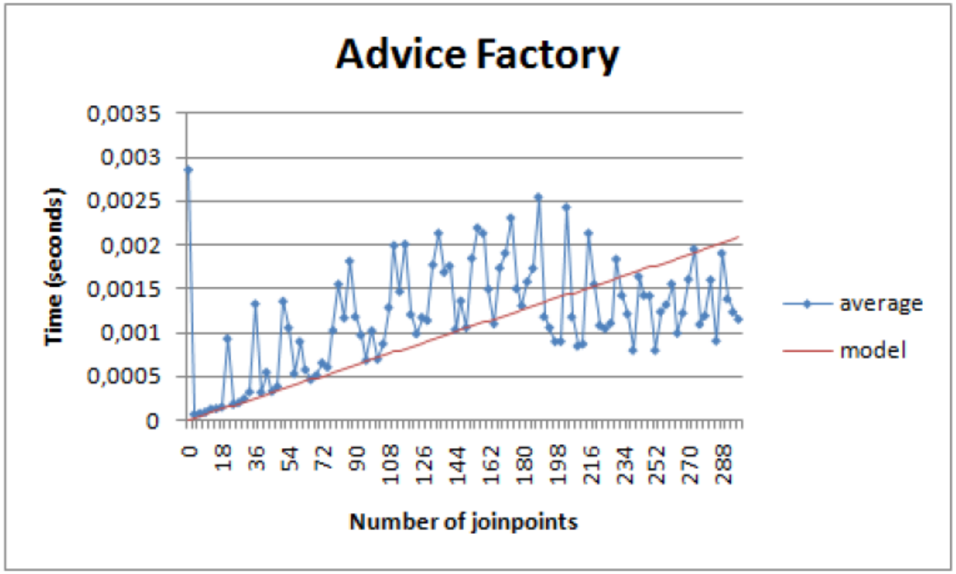
A : duration of instance of advice generation

k : number of combination

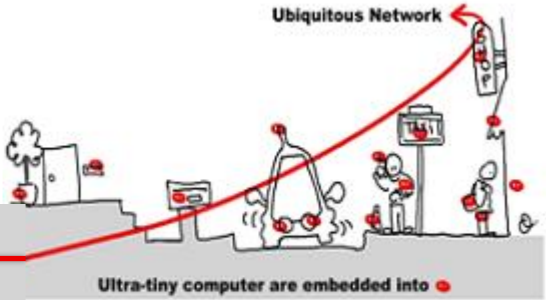
w : number of advice rule

$a1;a2$: model parameters

$$A = a1 \times \sum_{k=1}^{i}(kw) + a2$$



Conflict Identification (4)



S : duration of instance of advice superposition

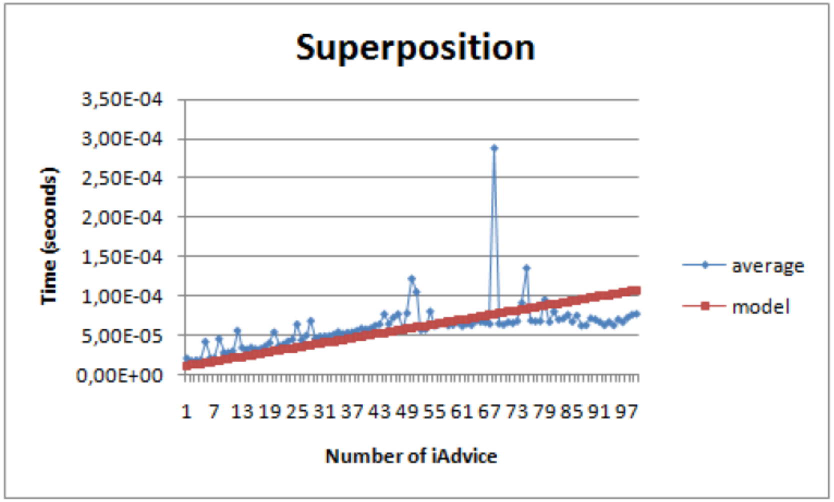
y : number of instance of advice

w : number of advice rule

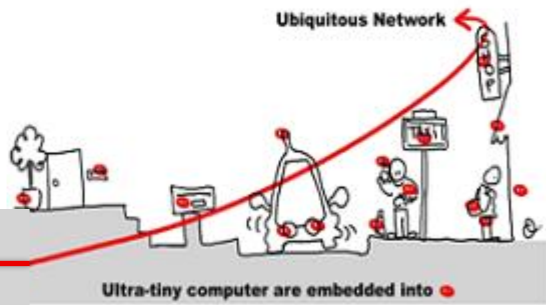
$g0$: number of rules in the initial instance of advice

$a1;a2$: model parameters

$$S = a1 \times \sum_{i=1}^{y} (w_i . g_0) + a2$$



Conflict Resolution, Example with ISL4WComp



- Duration of instance of advice merging

F : duration of instance of advice merging

g_o : number of rules in the base assembly

y : number of instance of advice

w : number of advice rule

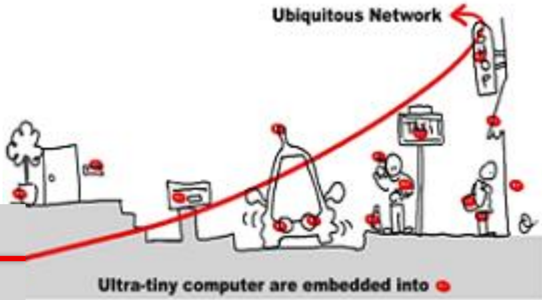
$a1$: model parameters

p_i : merging probability

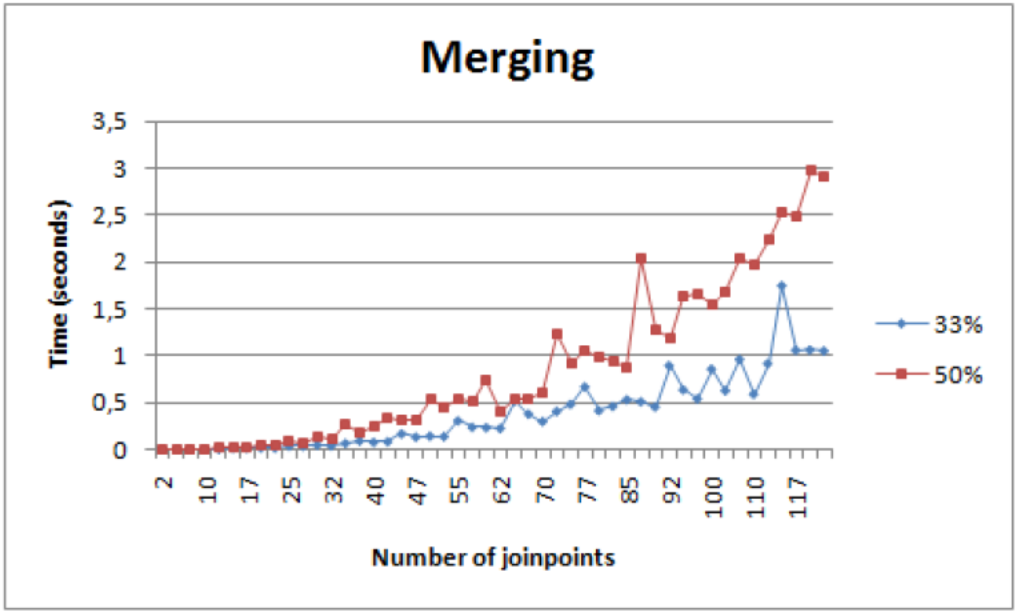
M : Cost of merging

$$F = a1.g_0 \times \sum_{i=1}^{y} w_i.p_i.M$$

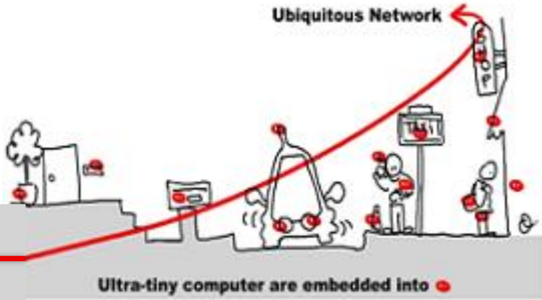
Conflict Resolution, Example with ISL4WComp



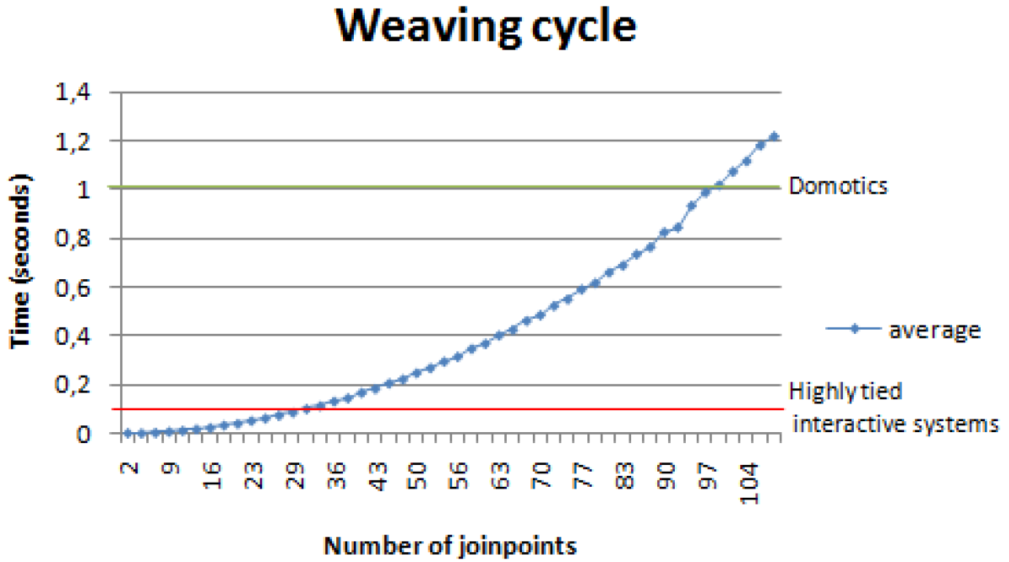
- Conflict resolution processing response time.
- Experiments : Response time average with C=33% and 50%



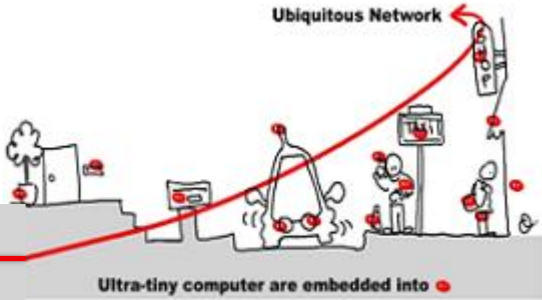
Synthesis : Overall Weaving Cycle



- Weaving cycles duration can be formally define as follows : W(n) = D(n)+C(n)+A(n)+S(n)+F(n) where n is the set of joinpoints from the base assembly.

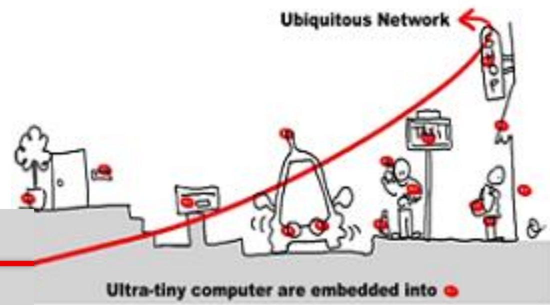


DEMO and future works



- Simple Demo : AA in WComp
- Other DEMO : AA in WComp

Future Works in WComp



- Multi-Domain weaving for AA to adapt Mobile Workers applications (Cf. CONTINUUM project of the French National Research Agency towards « Continuity of Service »)

- Adaptation trigered by physical environment variations

- Semantic adaptation : Improving of Pointcut Matching algorithms from Ontology-Based Metadata and mapping between ontologies (Cf. Continuum project of the French National Research Agency towards « Continuity of Service »)

7.4 Questions ?