Product Lines for Service Oriented Applications - PL for SOA

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WWV 2011

Reykjavík, Ísland
9 June 2011

Content

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SOA to enable the assembly, orchestration and maintenance of enterprise solutions to quickly react to changing business requirements

SPL to systematically capture and exploit commonality among a set of related systems, while managing variations for specific customers or market segments

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SPL to systematically capture and exploit commonality among a set of related systems, while managing variations for specific customers or market segments

$\Rightarrow$ 'How can the use of product line practices support service-oriented applications?'

Service Product Lines

- PLE technology increasingly finds its way to software sector
- SPLE can be considered as the most successful approach to intra-organizational reuse of software
- Combining SPL and SOA could become a new development paradigm that can help provide answers to the need for agility, versatility and economies
- Would achieve flexibility of network-based systems through service orientation, but still manage product variations through PLE techniques
- Service features are selected and/or parameterized at runtime by a user or by a product itself when a certain contextual change or a new service provider is recognized

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$\Rightarrow$ We adapt a feature-oriented PLE approach to SOC

Feature diagrams

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optional features may be present in a product only if their parent is present

mandatory features are present in a product if and only if their parent is present

alternative features are a set of features among which one and only one is present in a product if their parent is present

Feature models

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requires is a unidirectional relation between two features indicating that the presence of one feature requires the presence of the other

excludes is a bidirectional relation between two features indicating that the presence of either feature is incompatible with the presence of the other

Motivating example: Smart Grid

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Next-generation, managed electrical power system that leverages increased use of communications and information technology in the generation, delivery and consumption of electrical energy

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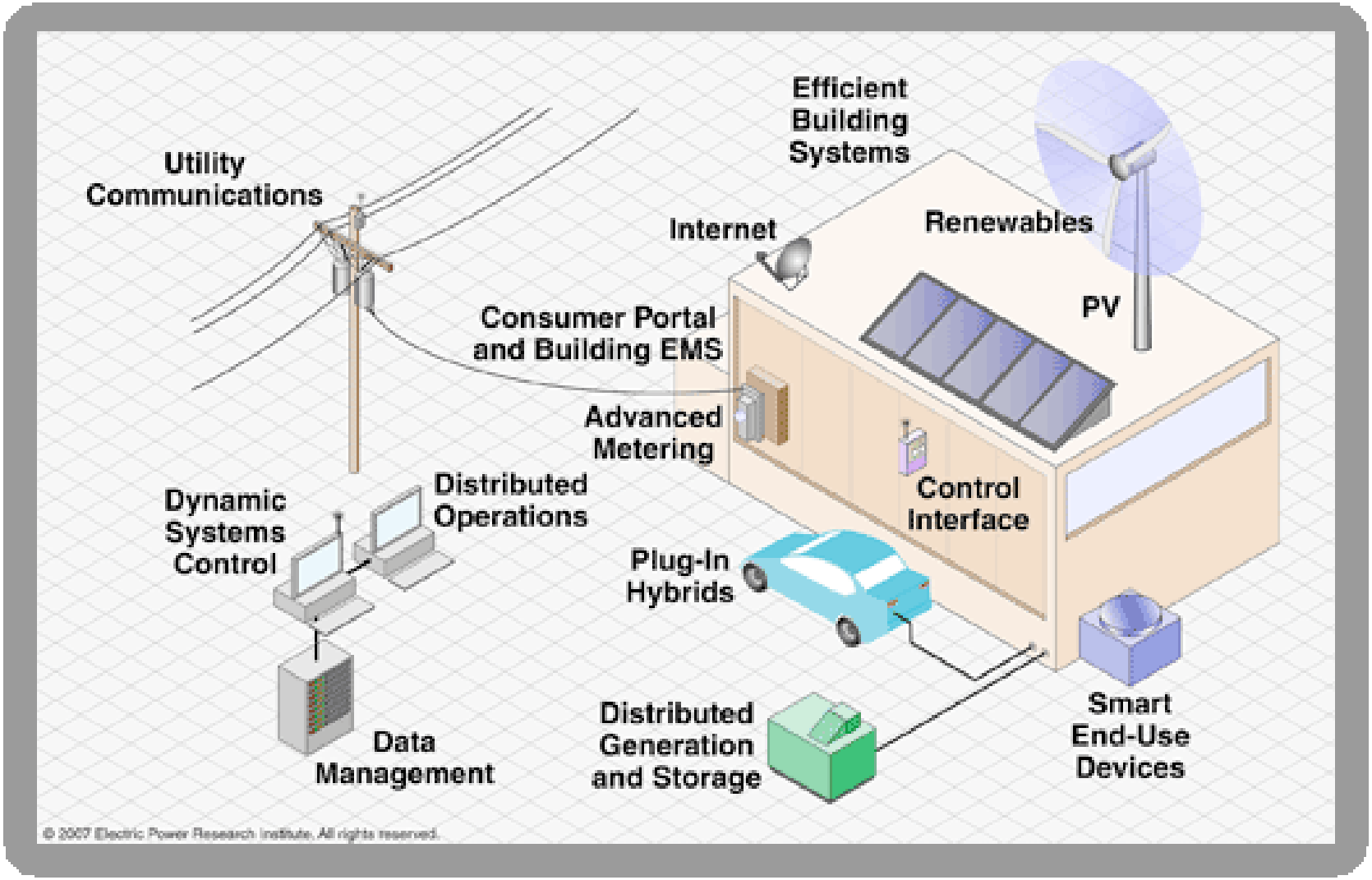
$\Rightarrow$ Consists of solutions based on both current and future telecommunication technologies for command and control, metering and charging

The Smart Grid (adopted from smartgrid.epri.com)



Properties of the Smart Grid

- Self-heal: enables the problematic elements to be restored with little or no human intervention
- Motivate and include the consumer in energy decisions
- Security: resists attack
- Provide power quality for 21st century needs
- Accommodate all generation and storage options
- Enable markets
- Optimize assets and operate efficiently

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$\Rightarrow$ End result: electricity provision as a service and the Smart Grid as a service product line

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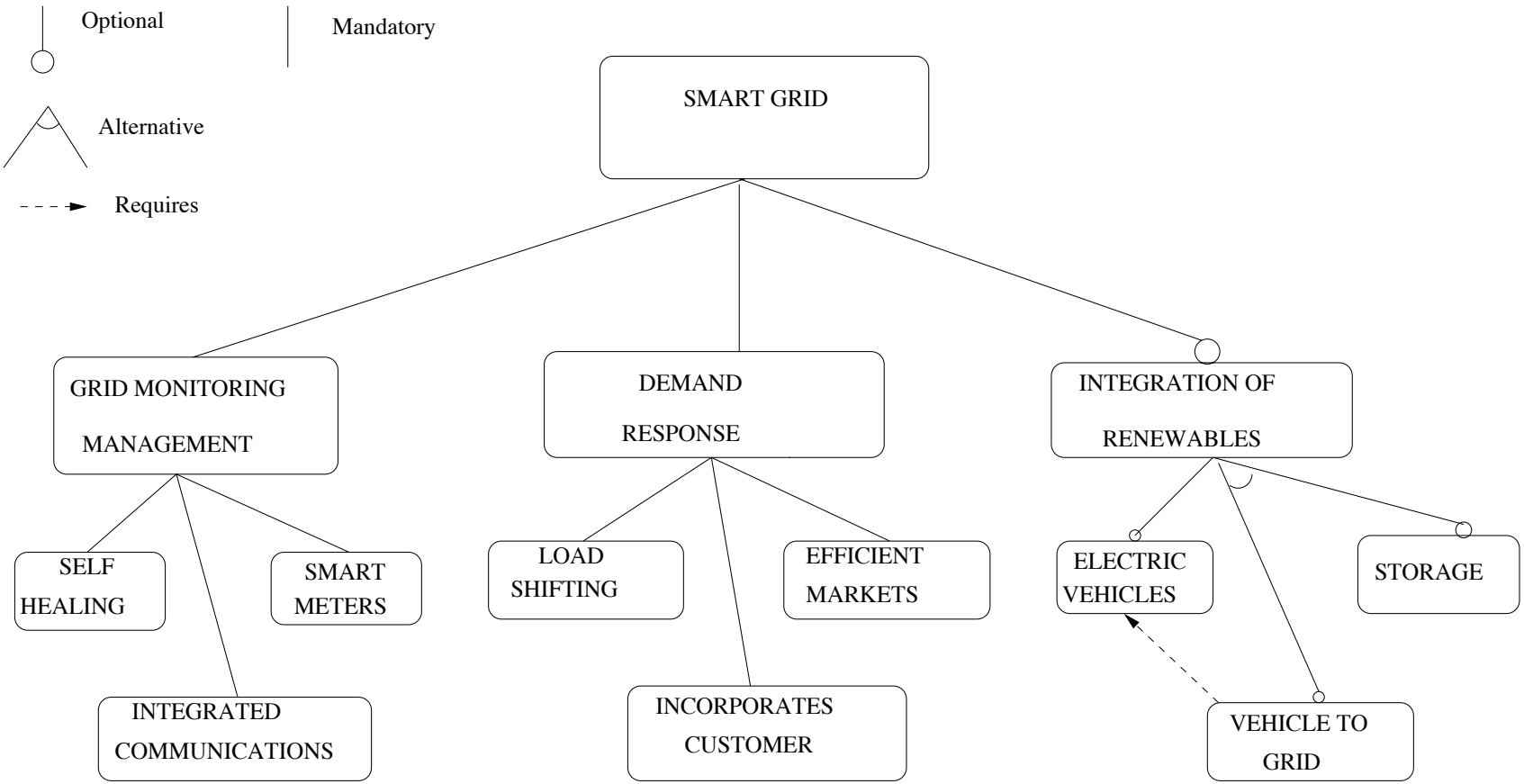
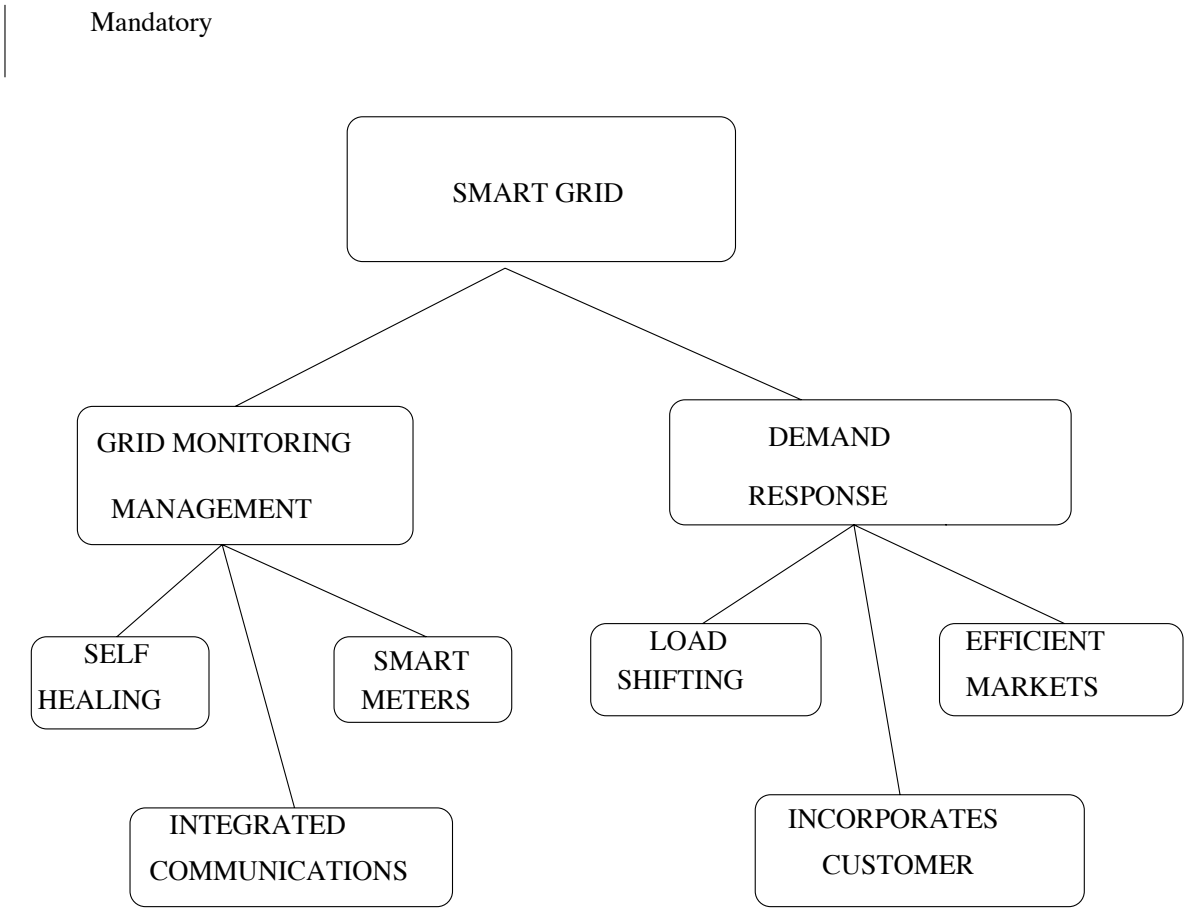
- Load shifting and V2G can reduce the energy storage capacity required to maintain power quality

Feature Model of the Smart Grid family



A derived product without integration of renewables



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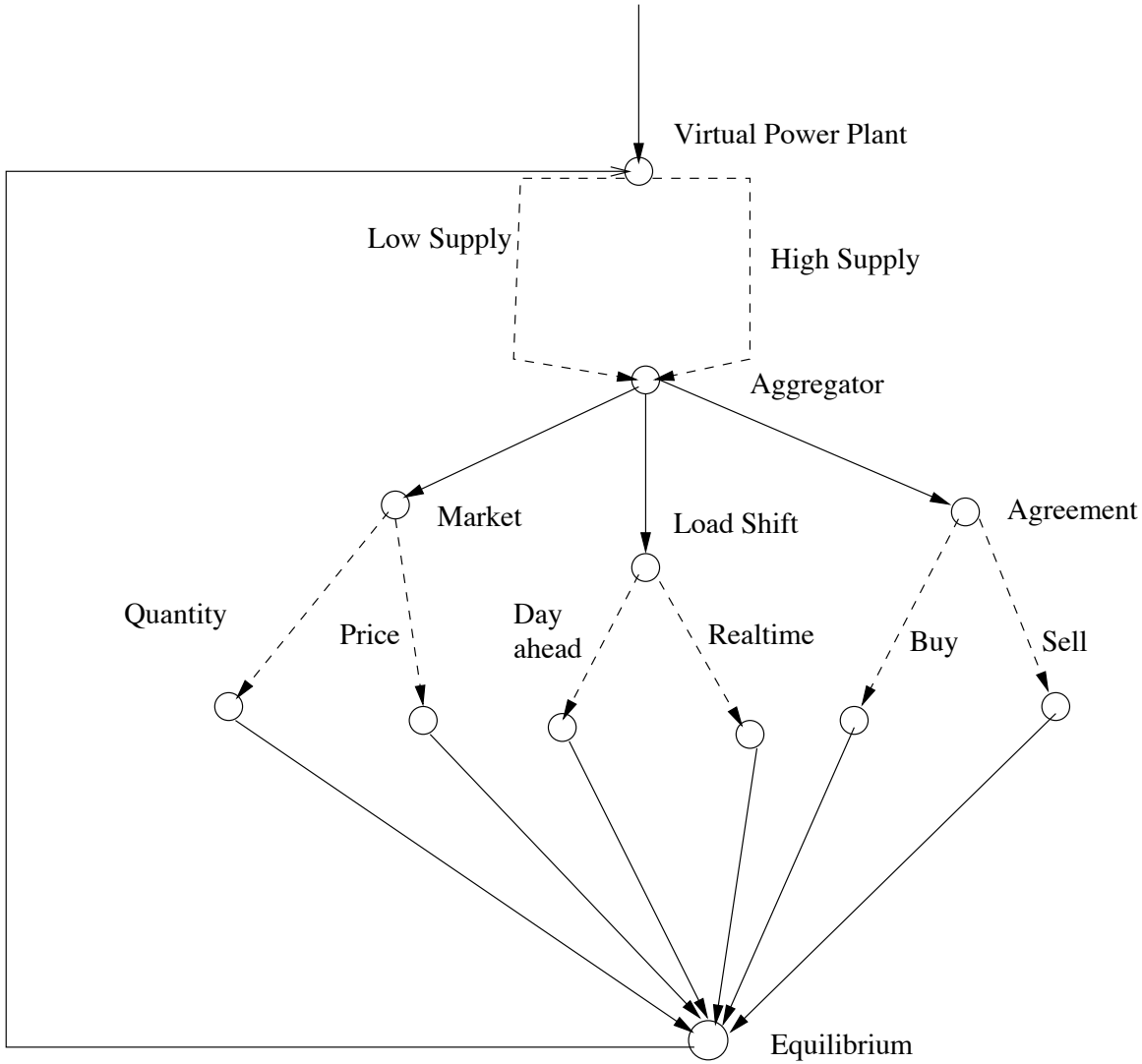
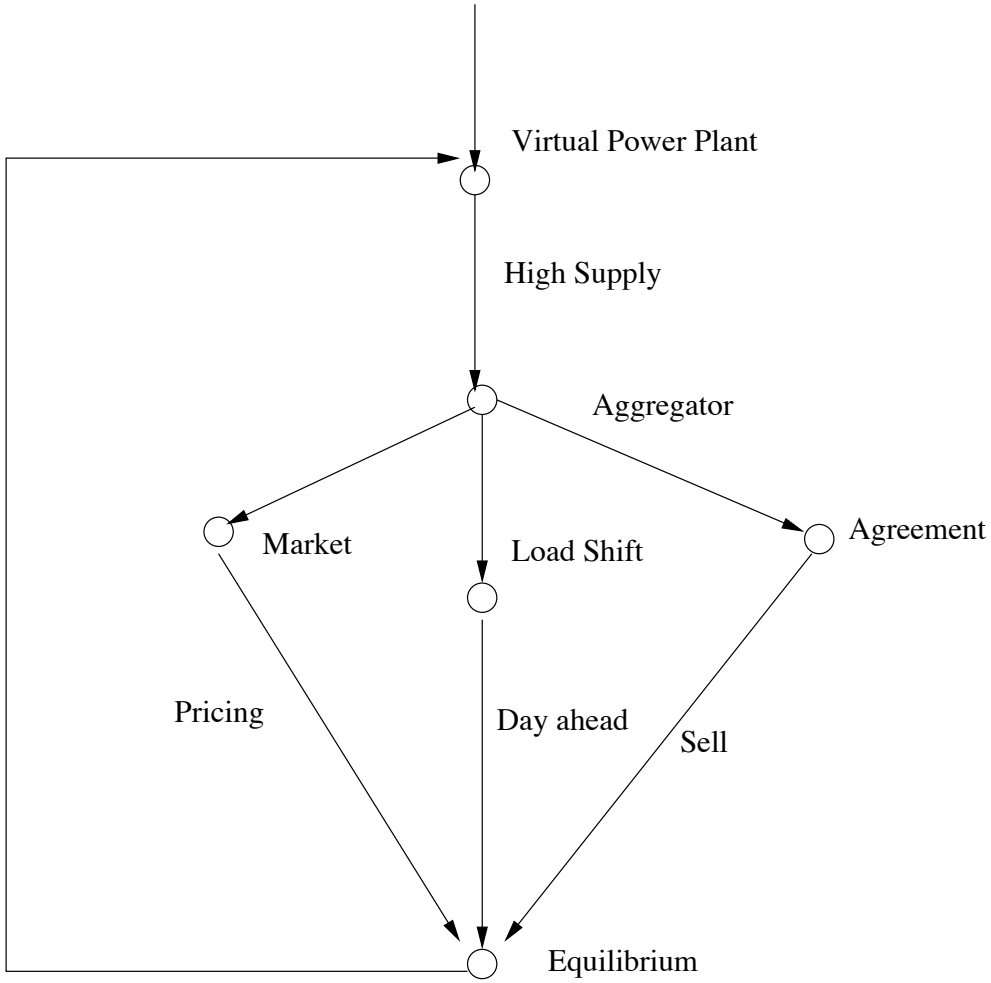
$\Rightarrow$ When the utility has excess supply of electricity, it will take advantage of existing agreements with their customers to sell and allow the system to get back to a state of equilibrium

MTS for the demand response function



Demand response behaviour when supply is high



Modal Transition Systems (MTSs)

Originally introduced by Larsen & Thomsen @ LICS 1988

MTSs are now an accepted model to formalize a product family's

- *underlying behaviour*, shared among all products, and
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We will model such advanced variability constraints by means of an associated set of logical formulae expressed in the variability and action-based branching-time temporal logic vACTL

Definition of MTS

$(Q, A, \overline{q}, \delta^{\Box}, \delta^{\Diamond})$ is an MTS with

- *underlying* LTS $(Q, A, \overline{q}, \delta^{\Box} \cup \delta^{\Diamond})$
- *may* transition relation $\delta^{\Diamond} \subseteq Q \times A \times Q$ (*possible* transitions)
- *must* transition relation $\delta^{\Box} \subseteq Q \times A \times Q$ (*mandatory* transitions)

By definition, mandatory transitions must also be possible: $\delta^{\Box} \subseteq \delta^{\Diamond}$
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Subfamilies/products obtained by preserving **all** must transitions, turning **some** may transitions into must transtions, and removing **some**/**all** remaining ones

Syntax of vaCTL: variability and action-based branching-time temporal logic

A temporal logic based on the “Hennessy-Milner logic with until”, but augmented with deontic *O* (*obligatory*) and *P* (*permitted*) operators, CTL’s path operators *E* and *A* and ACTL’s action-based Until operator, both with and without a deontic interpretation

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$$\phi ::= \mathit{true} \mid \neg\,\phi \mid \phi \wedge \phi' \mid \langle a \rangle\,\phi \mid [a]\,\phi \mid \langle a \rangle^{\Box}\,\phi \mid [a]^{\Box}\,\phi \mid E\,\pi \mid A\,\pi$$

$$\pi ::= \phi\ \{\varphi\}\ U\ \{\varphi'\}\ \phi' \mid \phi\ \{\varphi\}\ U^{\Box}\ \{\varphi'\}\ \phi'$$

Defines state formulae ϕ, path formulae π and action formulae φ (boolean compositions of actions) over atomic actions $\{a, b, \ldots\}$

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$\langle a \rangle^{\Box}$ and $[a]^{\Box}$ represent classic deontic modalities O and P, resp.

vaCTL: semantics with MTS as interpretation structure

- $q \models true$ always holds
- $q \models \neg\phi$ iff not $q \models \phi$
- $q \models \phi \wedge \phi'$ iff $q \models \phi$ and $q \models \phi'$
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- $q \models A\,\pi$ iff $\forall\, \sigma' \in path(q)$ such that $\sigma' \models \pi$
- $\sigma \models \phi\ \{\varphi\}\ U\ \{\varphi'\}\ \phi'$ iff $\exists\, j \geq 1 : \sigma(j) \models \phi'$, $\sigma\{j\} \models \varphi'$, and $\sigma(j+1) \models \phi'$, and $\forall 1 \leq i < j : \sigma(i) \models \phi$ and $\sigma\{i\} \models \varphi$
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Abbreviations: $EF\phi = E(true\ \{true\}\ U\ \{true\}\ \phi)$; $AG\,\phi = \neg EF\,\neg\phi$;
$EF^{\Box}\phi = E(true\ \{true\}\ U^{\Box}\ \{true\}\ \phi)$; $EF\ \{\varphi\}\ true = E(true\ \{true\}\ U\ \{\varphi\}\ true)$;
$EF^{\Box}\{\varphi\}\ true = E(true\ \{true\}\ U^{\Box}\ \{\varphi\}\ true)$; $AG^{\Box}\,\phi = \neg EF^{\Box}\,\neg\phi$; etc.

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No temporal ordering among related features: duty of behavioural LTS/MTS description of product/family, verifiable with vACTL

The SOA of the utility industry

We incorporate feature modeling into a SOA framework

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The major expectations and requirements are as follows

- The smart grid must provide all consumers with a highly reliable, flexible, accessible and cost-effective power supply
- End users will interact more with both markets and grids
- Electricity will be generated by centralized and dispersed sources
- Grid systems will become more interoperable to enhance security and cost-effectiveness

Service framework

- Like the Internet, the Smart Grid needs a standard layered architecture and needs to be distributed
- It will deliver electricity over a two-way protocol from supplier to consumer, utilizing independent components that must cooperate
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$\Rightarrow$ To model service product lines, we merge feature modeling and service-oriented concurrency calculus Orc

Orc

- High-level orchestration of services that coordinates interactions among basic subsystems, called sites, by use of a small number of combinators
- Language for task orchestration which can manage time-outs, priorities, failure of service and communication, which are features that are required for the Smart Grid
- Since developing a distributed system is notoriously difficult, this high-level language will make development and maintenance easier
- Combines a functional style with ideas from process algebra to aid the software engineer

Why Orc?

- Dynamic nature of the various components and services of the Smart Grid: dynamic service, market management and pricing are basic building blocks of a Smart Grid system
- Orc allows for the dynamic combination of services and the dynamic reconfiguration of software systems: idea is to invoke published services instead of developing isolated functions
- The semantics is operational, asynchronous and based on LTSs, which we hope to extend to MTSs and create a PL for SOA calculus in the future

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- Sites are nondeterministic: a site may publish either nothing, or a value, but typically the value itself may not be uniquely determined
- When sites are combined independently in parallel, even if each is deterministic, the result is not, because the order of publication is not determined and so interleaving occurs
- Each site, and the result of each Orc computation, is modeled as the set of what it may publish (i.e. as a set of sequences of publishable values)

Orc combinators

- The *independent parallel combinator*, $(A|B)$, of expressions A and B, publishes anything published by A or B independently
- The sites called by A and B individually are called by $(A|B)$ and the values published by A and B are published by $(A|B)$

Orc combinators continued

- The *sequential combinator*, $(A >x> B)$, initiates a new instance of B for every value published by A whose value is bound to name x in that instance of B
- The values published by $(A >x> B)$ are all instances of those published by B
- If A fails to publish, then so does $(A >x> B)$
- If x is not used in B, combinator is abbreviated by $(A \gg B)$

Orc combinators continued

- The *asymmetric parallel combinator*, $(A \ <x< \ B)$, evaluates A and B independently, but the site calls in A that depend on x are suspended until x is bound to a value
- The first value from B is bound to x, evaluation of B is then terminated and suspended calls in A are resumed; the values published by A are those published by $(A \ <x< \ B)$
- If B fails to publish, then so does $(A \ <x< \ B)$; but, otherwise, $(A \ <x< \ B)$ publishes the result of A's invocation with the first publication of B
- If x is not used in B, combinator is abbreviated by $(A \ll B)$

Orc combinators continued

- The *otherwise combinator*, $(A; B)$, executes A and if it completes and has not published any values, then B executes
- If A publishes one or more values, then B is ignored; the publications of $(A; B)$ are thus those of A if A publishes, and those of B otherwise

Orc combinators for features

Orc combinators have an almost one-to-one correspondence with the feature relations of feature diagrams:

- The independent parallel combinator, $(A|B)$, can be used to specify mandatory features
- The sequential combinator, $(A\ >x>\ B)$, can be used to specify required features
- The asymmetric parallel combinator, $(A\ <x<\ B)$, can specify optional features
- The otherwise combinator, $(A\,;B)$, can be used to specify alternative features, especially when there is a preferred feature or priority

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- We utilize the site **let** (x, y), which returns values as a tuple when it receives the second value

$$\textbf{let}\ (u, v) < \mathit{Load\_shift} < (\mathit{real\_time}|\mathit{day\_ahead}) < \mathit{Agreement} < (\mathit{sell}|\mathit{buy})$$

- The values published by this expression are those contained in **let**, which acts as container for the first result published and releases both when the second value is received

Conclusions and future work

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We intend to extend the LTS-based semantics of Orc to an MTS-based semantics in order to utilize the vACTL logic for verification

Publicity

Service-Oriented Architectures and Programming SOAP track @ 27th Annual ACM Symposium on Applied Computing (SAC 2012)

$\Rightarrow$ `http://www.itu.dk/acmsac2012-soap/`

IMPORTANT DATES (strict)

August 31, 2011: Paper submission
October 12, 2011: Author notifications
November 2, 2011: Camera-ready copy
March 25-29, 2012: SOAP @ SAC 2012