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Lecture 2: A Scalable Control Plane Architecture

Prof. Joe Sventek
joe@dcs.gla.ac.uk

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Complexity, anyone?

- As the industry continues its inexorable rush to multi-service networks, the following complexities result
  - The number of active elements in the network are exploding to handle the exponentially-increasing traffic
  - The transmission rates of individual interfaces is quadrupling every 3-5 years
  - We are coercing many high-speed streams of data onto a single fibre
  - The mix of traffic types requires the introduction of QoS mechanisms and policies into the network
  - Manual management of these complex beasts is no longer sufficient to meet customer guarantees
- One important question to answer: how can we guarantee first time, every time success in the configuration of such complex management systems?

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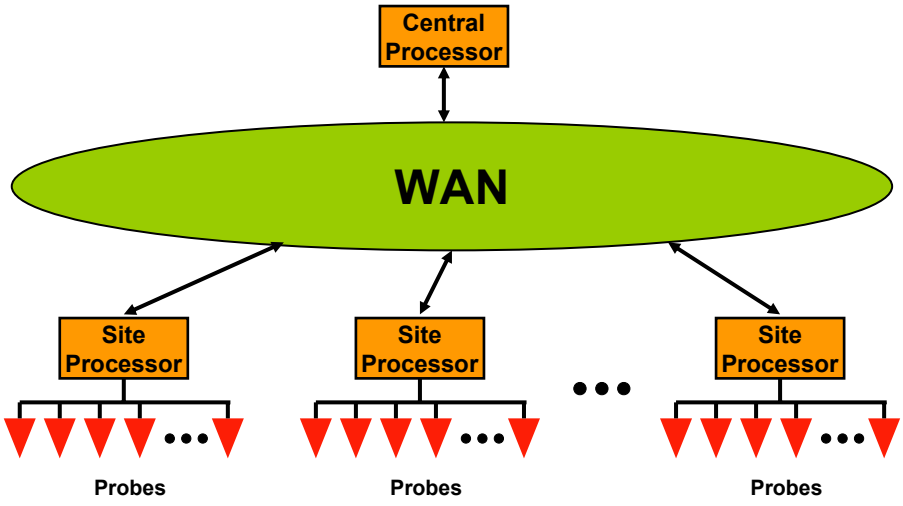
acceSS7 Architecture



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SS7 Example - Relative Sizing

- Links per site – up to 2000
- Links per probe – maximum of 8, average of 4

  $\Rightarrow$ 250-500 probes per site
- Sites – up to 2000
- Applications @ probe processor - up to 200
- Applications @ site processor - up to 20
- Worst case situation
  - $>10^6$ processor components
  - $> 2 \times 10^8$ software components

Traditional Configuration Approaches

- Traditional configuration solutions to these kinds of management applications have the following design:
  - Application components are configuration naïve – all configuration is performed outside of the components
  - The dependencies between components are captured in a database
  - The configuration/reconfiguration act itself is specified in scripts, driven by the dependency information, from a central location; the scripts are traditionally written to activate the application components in a lock step fashion, consistent with the dependency graph
  - Where parallelism is legal, it is achieved through complexity in the scripts
- In short, such configuration solutions melt down when confronted with an application the size of acceSS7.

Asymptotic Configuration

- Applications like Call Detail Record generation in acceSS7 are of a class that we refer to as background monitoring and management. These applications are required to be 24x7, while supporting *in situ* reconfiguration.
- These types of applications can deliver value to the customer long before all components have achieved the correct configuration.
- Our approach to achieving better scalability for this class of applications is based upon three premises:
  - Make the components responsible for configuring themselves correctly
  - Use multi-cast communication wherever possible to enable communications costs that scale substantially better than linearly in the number of components
  - Use replicated databases and randomization of access to avoid congestion when accessing the configuration database

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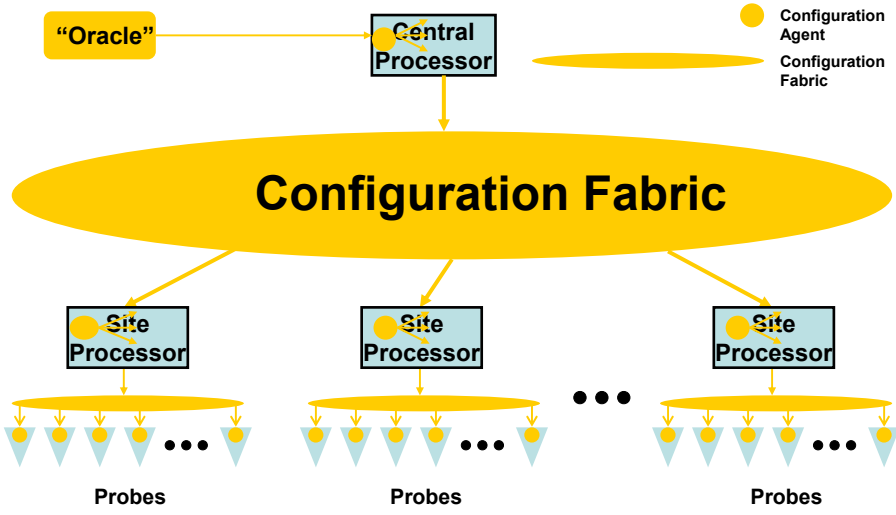
Configuration Architecture



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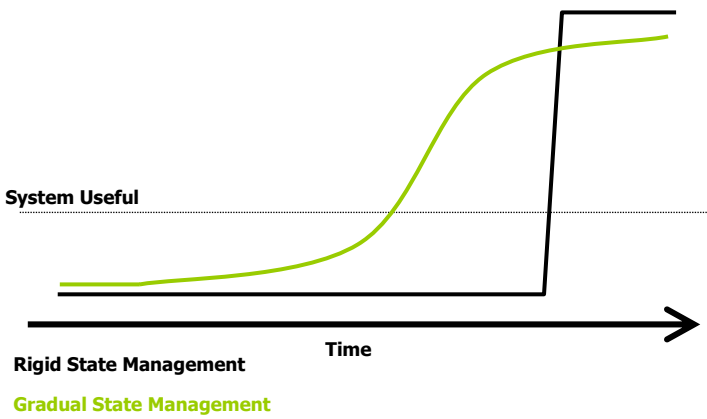
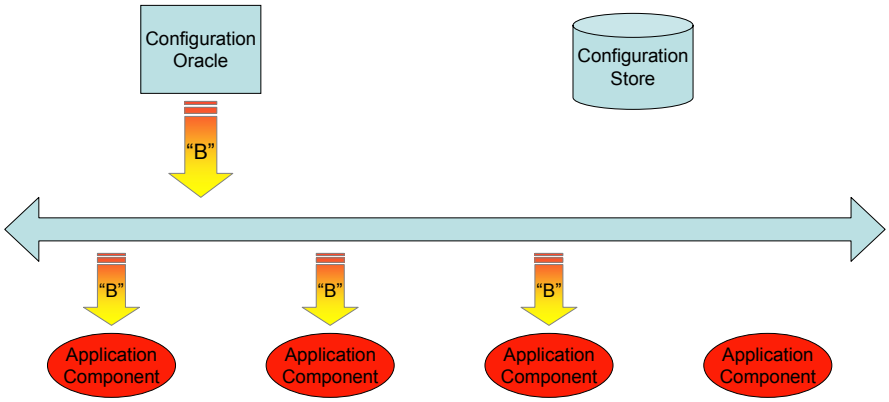
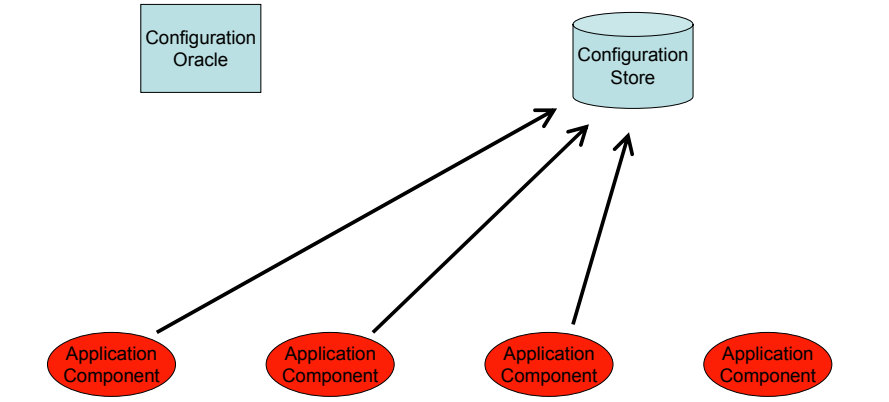
Rigid vs. Gradual State Management



Gradual Configuration



Gradual Configuration



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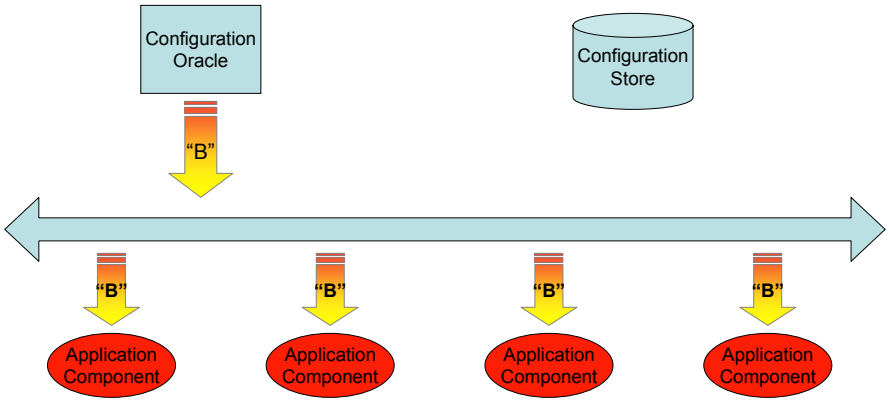
Gradual Configuration



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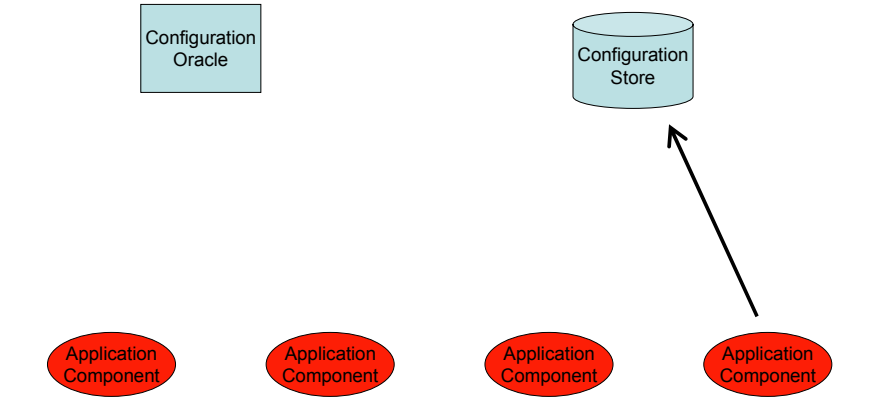
Gradual Configuration



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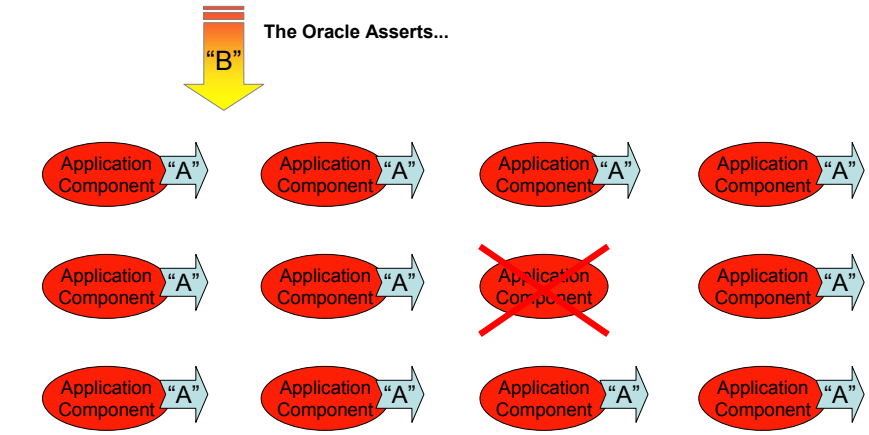
Approaching Equilibrium



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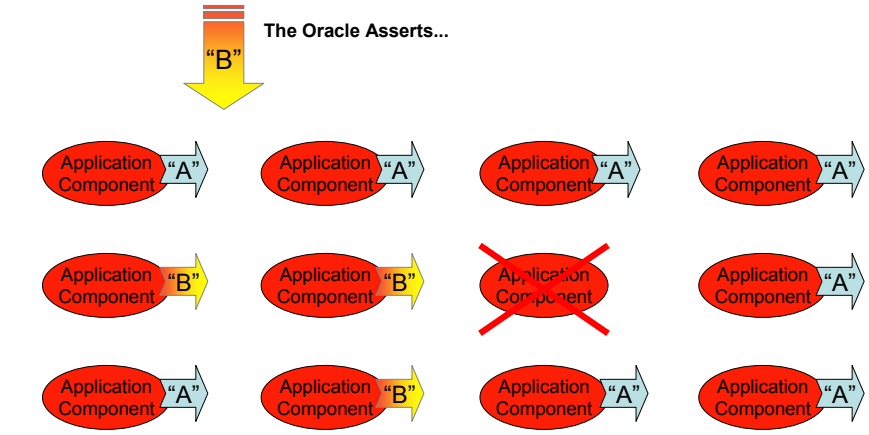

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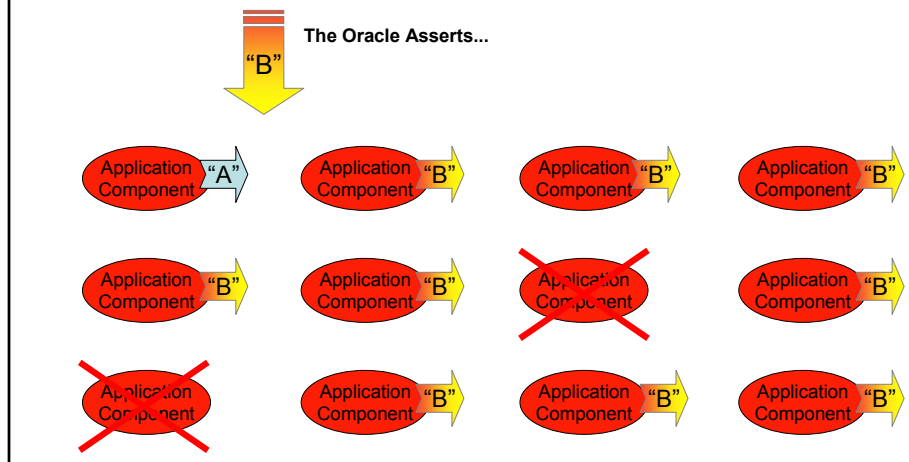
Approaching Equilibrium



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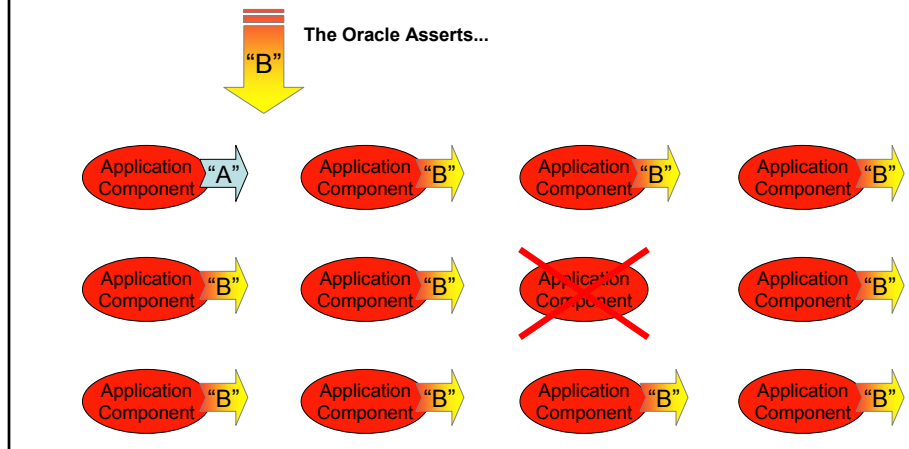
Approaching Equilibrium



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Critical Concepts...

- Applicable if the application can be useful when a subset of components are executing correctly
- Enables use of (but does not require) unreliable multicast communications
- Enables the system to become usable faster and be more robust
- Permits systems to be self-healing
- Requires some design time consideration and configuration-awareness on the part of application components
- Implies fine-grained & continuous monitoring
- Scales to extremely large systems

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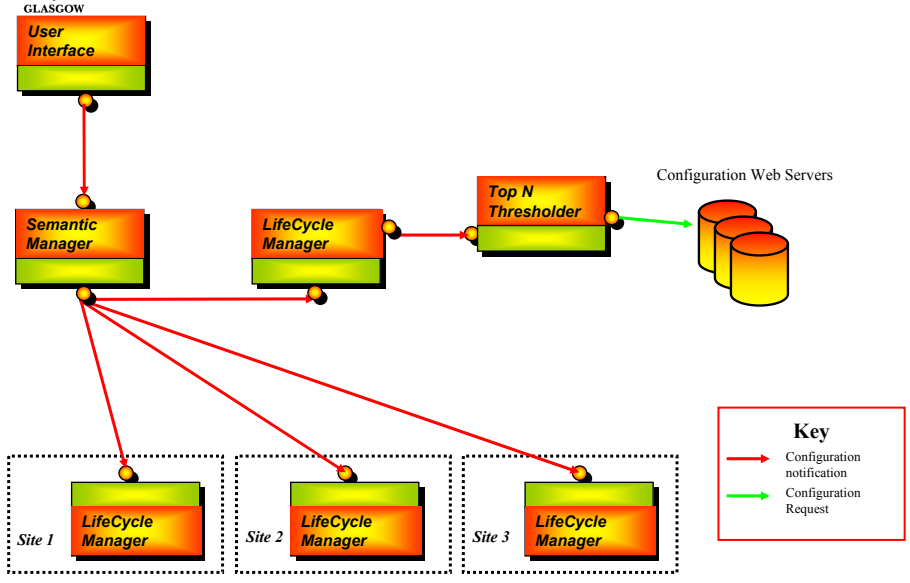
Central Site Configuration



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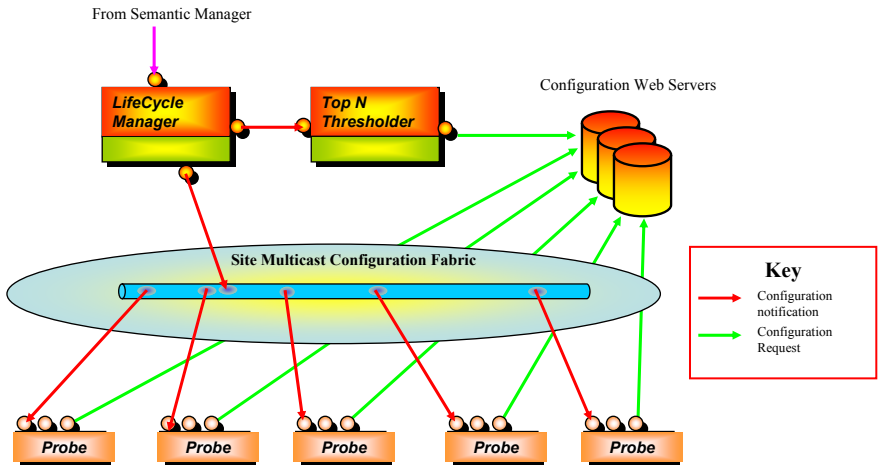
Probe/Site Level Configuration



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Status Monitoring

- The status of a Component can be derived in 2 ways :
  - Actively : you can ask/have the component tell you its state.
  - Passively : you can infer the state of the component by observing its behaviour.
- The Prototype uses both approaches.
  - Thresholders report their state directly to 'Status Monitor' Components.
  - The Status Monitor components 'snoop' on Probe traffic.

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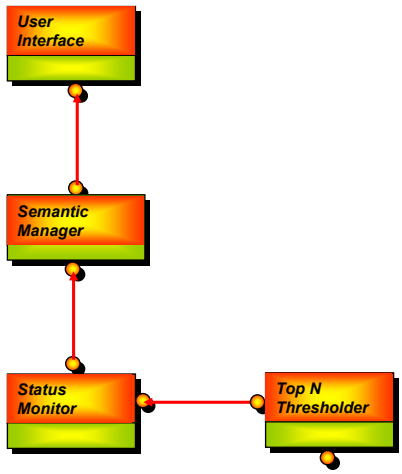
Central Site Status Monitoring



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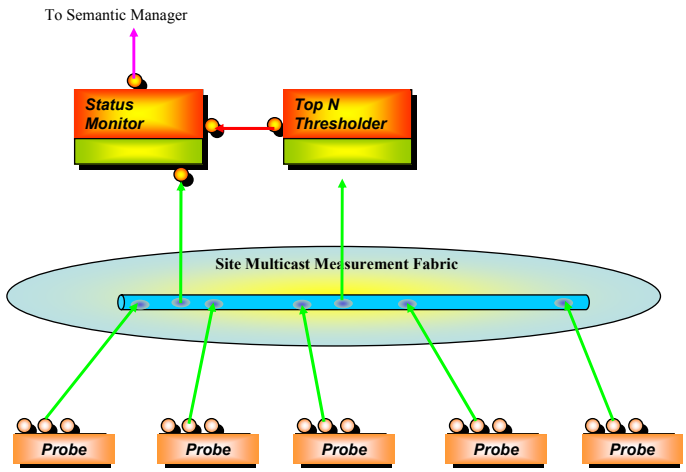
Probe/Site Level Status Monitoring



Implementation Specifics

- All code implemented in Java (configuration traffic is not the bottleneck for these systems)
- "Oracle" asserts correct state every 15 seconds
- Unreliable multi-cast used for communicating configuration updates to probes; reliable point-to-point used between central site and site processors
- Reliable multi-cast used to communicate tagged data from probes to site processor; reliable point-to-point used between sites and central
- Full replication of configuration databases; each component picks a random copy from which to retrieve its data

Lessons learned

- >90% of the probe components moved to the correct configuration after the first multi-cast of a new configuration
- Communicating two states, current and future+time, permits almost instantaneous change to a new state, subject to the synchronization of the processor clocks
- The prototype system was stable when confronted with constant configuration changes
- The prototype took no appreciable difference in the time necessary to converge as the number of probes grew; since the prototype used pt-to-pt communications between central and sites, its scalability is much more dependent upon the number of sites. For a truly large number of sites, a form of WAN multi-cast must be used