StarBED
A Large Scale Network Emulator

Yoichi Shinoda
Japan Advanced Institute of Science and Technology

What is the StarBED（*BED）?

- It's an Internet Emulator:
  - Re-configurable to follow user requirements
  - Large scale
  - Flexible
  - Hardware based
  - Internet Emulator / Simulator

2

StarBED Internet Emulator Concept

- Multi-purpose facility
  - Testbed for research and development
  - Testbed for deployment test
  - Analytic-bed for behavior analysis
  - Educational testbed
- Covers most of the up-stream to down-stream process of network related technologies and products.
- Origin of the name StarBED（*BED）
  - Testbed for * （= any）
  - A *star-bed* where new stars (ideas & technologies) spawn.

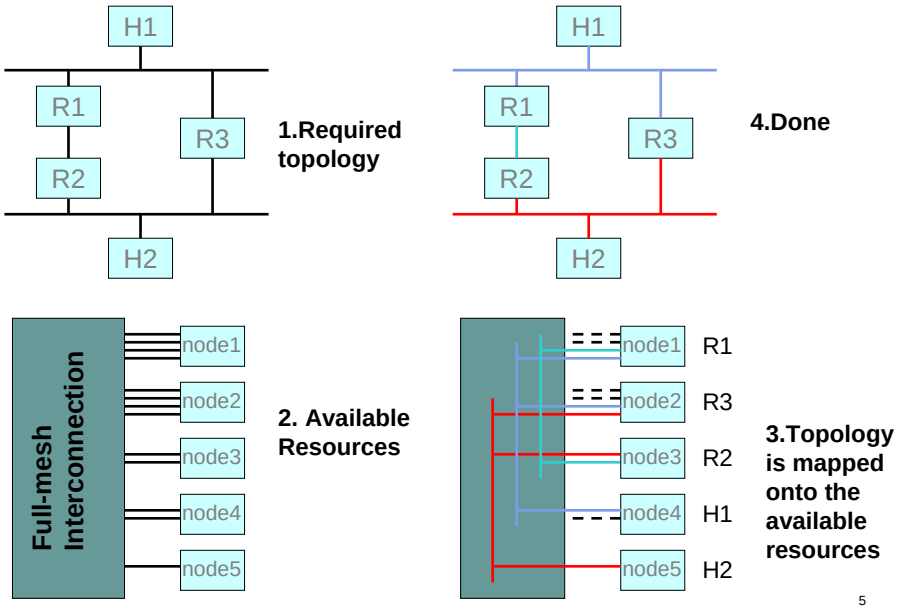
3

The StarBED Project

- Funded by NICT (National Institute of Communication
- 4 year project（2002 – 2005）
- Open research facility emphasizing industrial-academic-governmental joint research.
- Can also be used by industries alone (and can even choose not to disclose their results!)

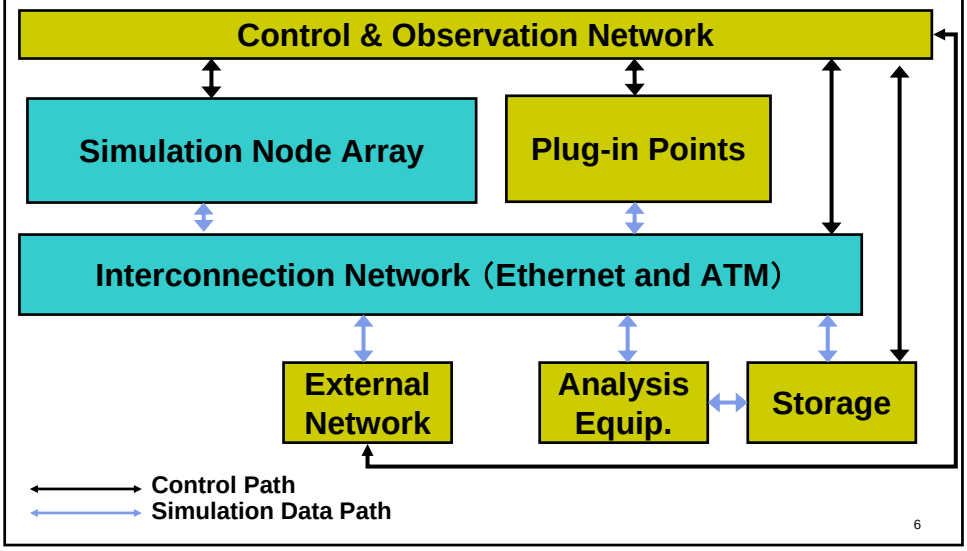
4

Configuring the emulator

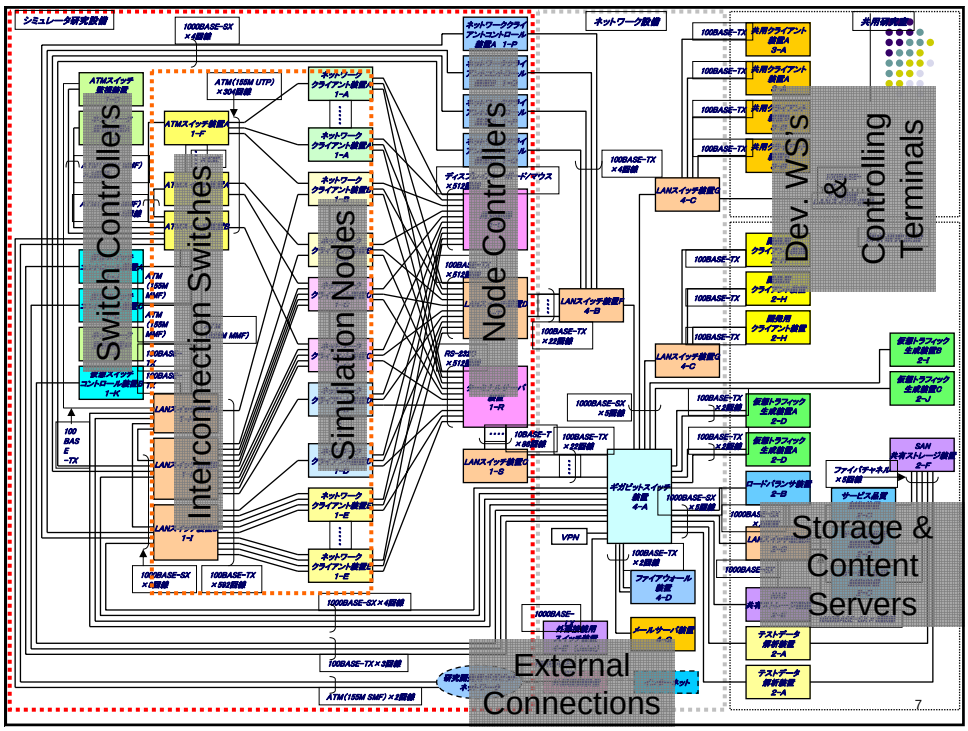


5

StarBED design (conceptual)



6



H/W features of the StarBED (1)

- Interconnection switches provides L2 topology
- Physical emulation nodes
  - 512 nodes max.
  - 1U PCs @ 900MHz Pentium III, 512MB Memory
- Virtual machine multiplexed emulation
  - 5120 nodes max. (x10 VM-multiplexing in design, x4 actual experience)
- L3 Routing emulations
  - PC-based routers
  - Installation of commercial routers at plug-in points
- Not good for experiments / simulations with precise timeing requirements (ouch!)

8

H/W features of the StarBED (2)

- External connectivity
  - External connectivities are available for both:
    - Control Path
    - Simulation Data Path
- Connection to JGN-II
  - 10GbE **(λ-enabled)**
  - JGN can be used as a part of the simulator
- Connection to JAIST
  - 10GbE connection via Science Park LAN (dark fiber) Provides Internet Connection
  - Provides access to JAIST's computing resources (MPP, Storage)

9

The actual StarBED facility

10

Application areas of the StarBED

- Research and development platform
- Behavior analysis of exisiting softwares
- Large scale isolated environment
- Internet measurement device
- Educational platform
- Reconfigurable cluster computer
- … Anything that requires set of network nodes and interconnection networks.

11

Applications of the StarBED (1)

Research and Development Platform

- Properties of R&D on real-networks:
  - Low efficiency
  - Low code and system coverage
  - Hard to reproduce the same environment
  - Impacts commodity traffic
  - Low reproduction
- A large scale Internet emulator may solve these problems.

12

Applications of the StarBED (2)

Analysis of the Internet and Internet Applications

- It is HARD to understand the Internet:
  - Yet unknown traffic characteristics of the Internet.
  - It changes over time (and dominating applications); continuous research is required.
    - Legacy applications (E-mail, ftp, telnet, …)
    - Web-centric applications (Now)
    - P2P applications (Emerging)
    - Stream-oriented applications (Emerging)
    - Some, brand new applications (Future)
  - Some key software (e.g.: BGP & DNS) are only understood through experiences.

13

Applications of the StarBED (3)

Large scale isolated environment

- Internet-sized emulation that is strictly isolated.
  - DoS and DDoS emulation.
  - Infection mechanism and strength of computer viruses.
  - Training facility for emergency response teams.
  - Network sized ***honey-pot*** that attracts malicious users (this one is not isolated).

14

Applications of the StarBED (4)

Internet measurement device

- It is possible to (virtually) place StarBED nodes over the wide region in the Internet using PPPoE and L2TP technologies.
- StarBED can be a collection of probes placed widely and distributedly over the Internet.
- Applications examples
  - Let nodes participate in un-managed P2P networks.

15

Applications of the StarBED (5)

Educational platform

- Next generation human resources lack opportunity to plan, design, implement, operate and manage an Internet sized network. They need try & error experiences with:
  - Fundemental design.
  - Large scale networks.
  - Complex routing.

16

Applications of the StarBED (6)

Re-configurable cluster computer

- Grid emulation, software development environment
- Re-configurable interconnection network:
  - Resolving hot-spots.
  - Transform process migration problems to topology configuration problems.

17

StarBED achievements:

Modeling experiences

- Through consultation with users of the StarBED, we have accumulated experiences on how to model the target system to fit into the StarBED environment.
- Experiments could be classified into two categories:
  - Extension of existing emulations.
    - Mostly for product level systems.
    - Known set of tools, predetermined verification items.
    - Scaling is the major concern.
  - Emulation of large or complex systems of the type that were never emulated before.
    - Verification items must be identified.
    - Abstraction based on verification items.
    - Custom modules for special emulation needs.
    - …

18

StarBED achievements:
SpringOS - Loosely integrated tool suite

- Tightly integrated all-in-one tools was hard to develop, and hard to use.
- Instead, we came up with collection of small tools each providing core functions and used as required.
- SpringOS component overview
  - Resource manager
  - Node software loader
  - Node disk management
  - Switch configurator
  - Scenario evaluator
  - Progress visualizer
  - Node health checker

19

SpringOS's Graphical Progress/Status Display

Topology specification

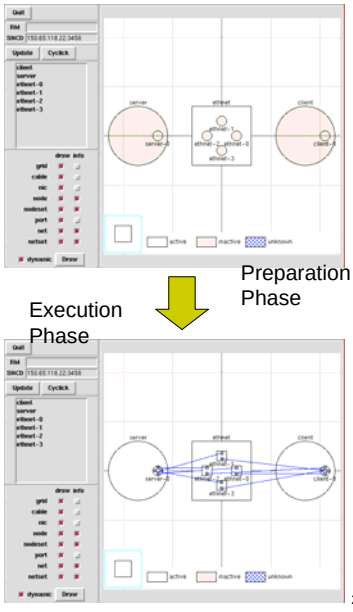
```
nodeset client class c num 1
nodeset server class s num 1
netset ethnet class e num 4

attach server.netif["lan0"] ethnet[0]
attach server.netif["lan1"] ethnet[1]
attach server.netif["lan2"] ethnet[2]
attach server.netif["lan3"] ethnet[3]

attach client.netif["lan0"] ethnet[0]
attach client.netif["lan1"] ethnet[1]
attach client.netif["lan2"] ethnet[2]
attach client.netif["lan3"] ethnet[3]
```

Execution specification

Described as sequences of remote program invocations and synchronization



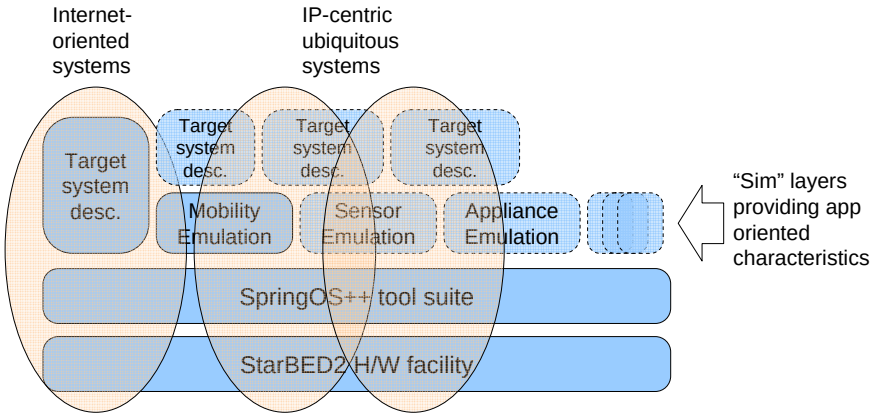
20

Expanding functionalities of the StarBED

- Helper modules
  - Mobility support
  - Realistic network modules (delay, loss, …)
  - Micro-node (embedded) processor emulation support
- Interaction with remote environments
  - Integration of remote target systems.
  - Integration of multiple testbeds.
- Semi-automatic generation of emulation environments and test vectors.
- Considerations about correctness of emulations, including soundness and completeness.

21

StarBED2 structure



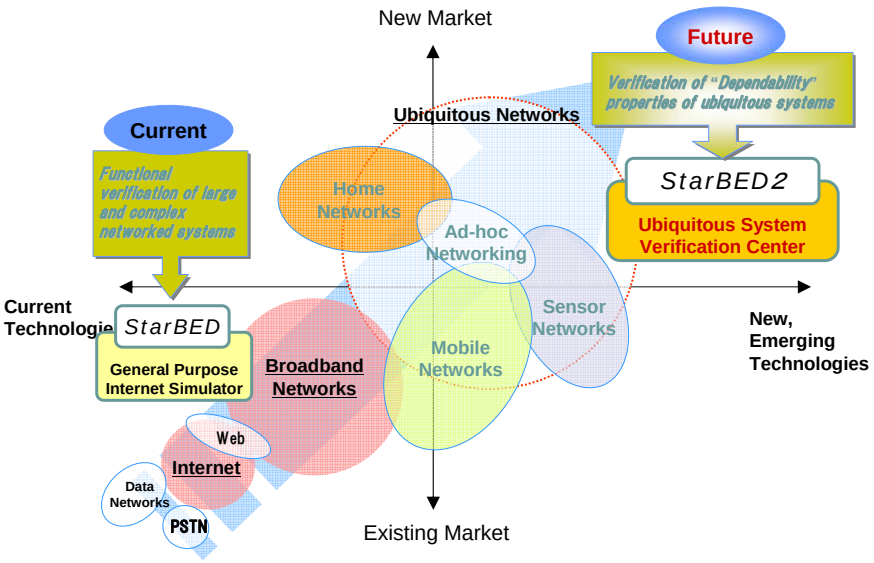
22

Expanding the mission of the StarBED

- Explicit support for emerging notions in ITC:
  - IP-centric systems
    - Non-Internet systems utilizing IP technology would play important roles in coming years.
  - Ubiquity
    - Number of entities that must be handled would increase by orders of magnitude.
  - Dependability
    - Experiences of simulations and emulations focused on verification of “functionality” and “performance” aspects.
    - A challenge: Verification of dependability of large and complex systems through emulations.

23

StarBED2 Mission Scope



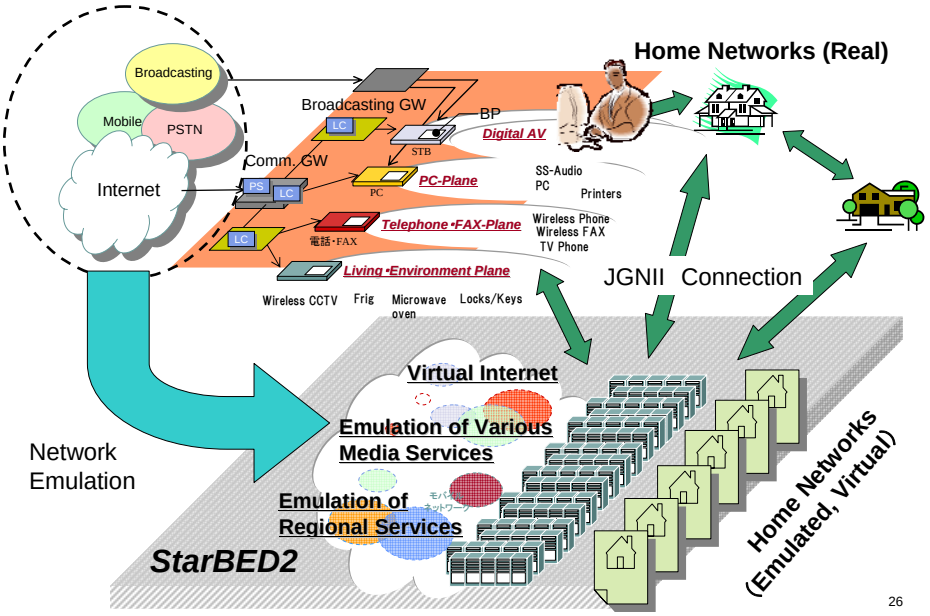
24

Challenge examples

- Town-sized network emulation
  - Hybrid reality-emulation approach in which couples of home networks are actually built, with rest of the town emulated in the StarBED.
    - How the town network react to wide area events?
- Management of 10M-order sensors
  - Volume of data itself will impose a problem.
  - Sensors may fail, data may be discarded in transit.
  - Failures and failure patterns themselves should be managed as meaningful data?

25

Town Network Emulation



26

Conclusion

- As different users with different emulation needs started to use the StarBED in full scale, we are accumulating:
  - More experiences with modeling/abstraction techniques
  - Tools for easier operation
  - Ideas for new application areas
- We are expecting more interesting results from experiments using the StarBED.
- The StarBED will be expanded to support verification of functionality, performance, and dependability of ubiquitous systems.

27