ExScal Backbone Network Architecture

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Dependable Distributed and Networked Systems

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Outline

- ExScal Introduction
- ExScal Backbone Network Hardware and Software
- ExScal Backbone Network Architecture
- ExScal Contribution
- Conclusion

Extreme Scaling

- ALineInTheSand [Arora'04]
  - 90 Mica-2s across 18m x 5m
  - Intruder detection, classification, and tracking in real time
  - Low cost, power efficient, robust, accurate, and self-configuring system
- ExScal [Arora'05]
  - 1000+ XSMs across 1260m x 300m
  - Scaling of low cost, power efficiency, robustness, accuracy, and self-configurability

Problem

- Reliability and Latency provided by sensor network is insufficient [Bapat'04]
- Hence, construct a backbone network
  - More reliable and faster
  - For a scale of 200 nodes
  - Still low cost, power efficient, etc.
- Network Choice: IEEE 802.11b
  - Ad-hoc mode of operation
  - Upto 54 Mbps bandwidth
  - Open standard

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ExScal Backbone Node Requirements

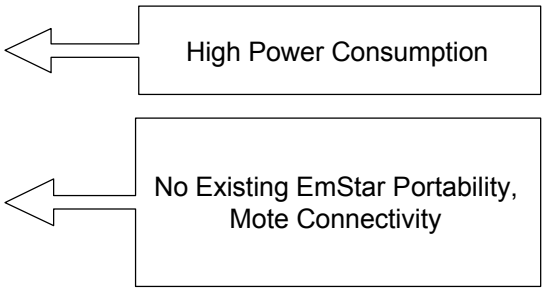
1. IEEE 802.11 enabled
2. Mote connectivity
3. A software development environment
4. Low power consumption and ability to manage power
5. Interface to connect GPS
6. Open source system software
7. Compact and lightweight
8. Low cost

Software Development Environment Requirements

- Tools to facilitate
  - Simulation
  - Deployment
  - Debugging
  - Visualization
- Rich library of commonly used function calls
  - Message packet buffers
- Event driven execution paradigm
  - For real time applications on embedded devices

ExScal Backbone Node + Software Selection [Cao]

- Stargate
- iPAQs
- Inhand
- BitsyX
- IntrinsycC



And, the winner is …… **Stargate + EmStar** !

Anatomy of XSS

- XSS: Extreme Scaling Stargate
  - Stargate
  - SMC 2532W-B High Power IEEE 802.11b PCMCIA card
  - BU-303 GPS Mouse - USB
  - 9dBi antenna of length 1.82m
  - 6DC-105 Lead Acid battery
    - 6V DC
    - 105 Ah current draw

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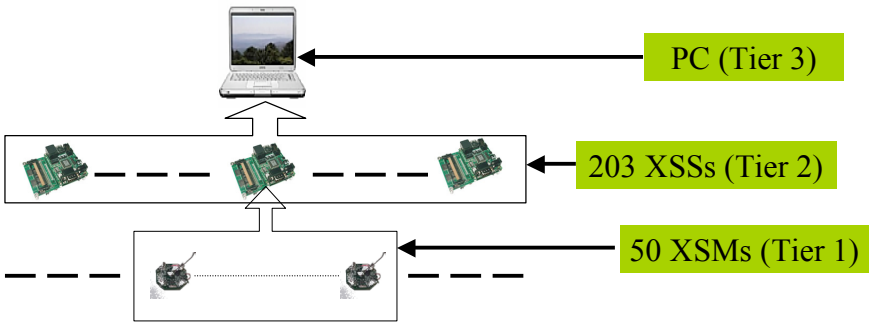
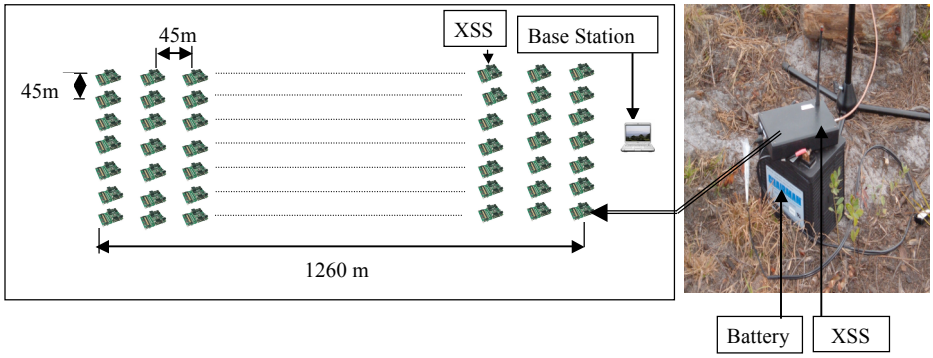
ExScal Network Hierarchy



ExScal Backbone Network (Tier-2) Topology [Kumar]

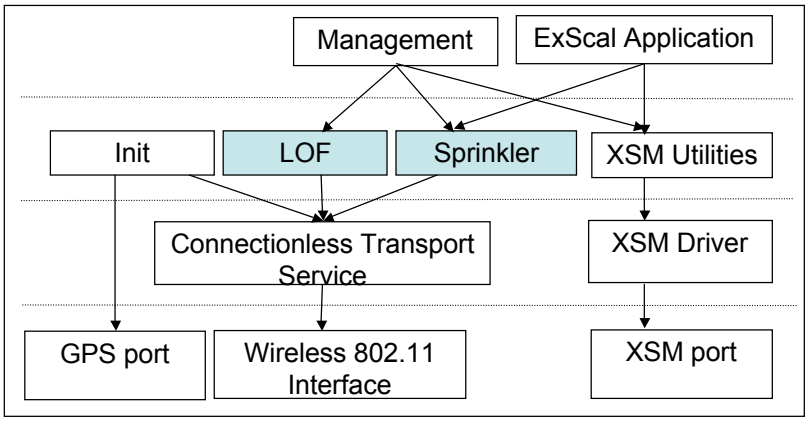


Challenges

- Previous largest deployment of IEEE 802.11 network was 30 - 40 nodes
  - Lack of tested routing protocols for a *multi-hop* network
- Energy Crisis
  - IEEE 802.11b ad hoc mode power management is not implemented in the driver
  - XSS can last for ~ 7 days, while required lifetime of network ~ 14 days

Operation	Current Draw
Processor	330 mA
Receive a packet	280 mA
Send a packet	650 mA

Backbone Node Architecture



The LOF [Zhang'05]

- Geography-based routing metric without assuming geographic uniformity
- Power Saving
  - Link quality estimated via beacons differs from that of data traffic
  - Beaconing consumes energy unnecessarily, especially when events are rare
  - Data-driven estimation, enabled by changing Linux Kernel as well as 802.11 driver

Comparison between LOF and Beacon-based Approaches

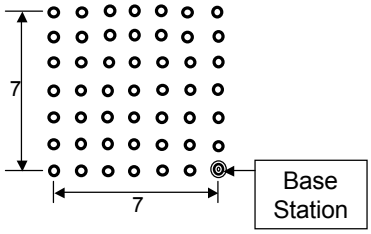
- Experiment setup
  - 195 Stargates deployed in a 15 * 13 grid
  - the stargate at a corner sends packets, according to ExScal traffic trace, to the stargate at another corner farthest away
- Results
  - End-to-end latency: reduced by a factor of 3 in LOF
  - # of transmissions per packet received: reduced by a factor up to 2.37 in LOF

The Sprinkler [Naik - Coming Soon]

- A reliable data dissemination service for wireless embedded devices
- Uses geographic locations of nodes and assumes a minimum density of nodes
- Currently implemented in Linux under EmStar for 32-bit machines e.g. PCs, Stargates, and iPAQs.
- Power Saving
  - Selects a subset of nodes (Connected Dominating Set) to broadcast data
  - Schedules transmissions (TDMA) to avoids collisions

Comparison between Deluge [Hui'04] and Sprinkler

- Experiment Setup
  - A network of 49 nodes



  - A payload of 240 data packets
- Results: Number of packets transmitted as compared to optimum
  - Deluge is **160.21 times** optimum
  - Sprinkler is **10.0 times** optimum

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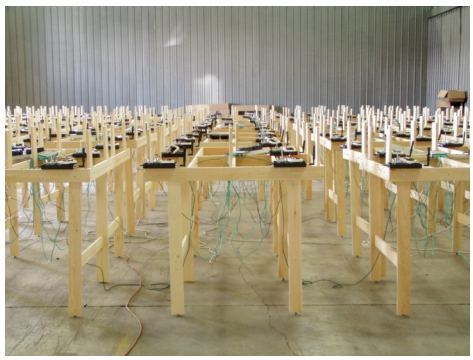
IEEE 802.11b Driver [Zhang]

- A wireless LAN interface with feedback
- Components
  - Linux kernel:
    - Add an IW-event type to carry feedback regarding successful transmissions
  - *hostap* driver:
    - Give feedback for both successful and failed transmissions
  - EmStar-based linxyd:
    - Interface between EmStar and *hostap* driver
- Challenge: Reliable feedback fetching
  - Avoid socket buffer overflow

Kansei [Naik et al'05]

- A test-bed containing 200 pairs of XSSs and XSMs
- A *multi-hop* IEEE 802.11 network
  - Using attenuators and S/W Tx power control
- Applications
  - Debugging
  - Measuring performances of protocols
- Online web interface
  - http://69.211.157.230/kansei



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Conclusion

- Important Issues in an Extreme Scaling Research
  - Power Management
    - Radio-based wakeup for ad hoc IEEE 802.11
  - Simulation and Debugging Tools
    - Large-scale (>> 200) simulation support in EmStar
    - Large-scale (>> 200) 'realistic' test-beds

Acknowledgements

- EmStar
  - Lewis Girod (UCLA)
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  - Dr. Trevor Pering (Intel Research)
  - Dr. Philip Buonadonna (Intel Research)
- Stargate Hardware System
  - Jaidev Prabhu (XBow)
- Deluge Comparison Analysis
  - Deluge: Jonathan Hui (UCB)
  - TOSSIM and Tython:
    - Dr. Philip Levis (UCB)
    - Joerg Claussen (DoCoMo Euro Labs)

- ExScal Website:
  - http://cast.cse.ohio-state.edu/exscal

Questions / Comments