Network Simulators, Emulators and Testbeds

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Outline

- Motivation for Research
  - Different Techniques
- Simulators
  - Assumptions/Axioms
  - Methods and Results
- Testbeds
  - Architecture
  - Different Testbeds
- Emulators
  - Architecture
  - Parameters and Results

The need for research

- Why do we need to research the modeling of Wireless Networks?
- Wireless Access Modeling increasingly important in years to come
- Techniques used for wired networks no longer work
  - Links not constant, reliable or physically isolated from each other
  - Single medium shared by many devices, including external uncontrollable sources
- Few readily available tools for modeling and prototyping
  - So current work relies on formal separation of radio and Networking Layers
- Need for cross-layer protocol research

The Need for Research (contd)

- Need a technique which satisfies following criteria
  - Repeatability
  - Experimental control
  - Realism (w.r.t lower layers)
  - Configurability and behavior modification
  - Automation and remote management
  - Isolation (from collocated networks)
  - Scalability
  - Integration with wired testbeds and networks
- Three techniques currently available
  - Simulators, Testbeds and Emulators
Introduction to Simulators

- NS-2
- OPNET Modeler
- GloMoSim
- SWAN

Benefits of Simulators

- Control
- Configurability
- Repeatability
- Manageability
- Integration
- Isolation
- Scale

Do Simulators Match Reality?

- Often use simplified MAC layer
- Modeled in detail, but miss layer interaction
- Often lagging behind current technology

- What about signal propagation?

Common Axioms

0: The world is flat
1: A radio’s transmission area is circular
2: All radios have equal range
3: If I can hear you, you can hear me
4: If I can hear you at all, I can hear you perfectly
5: Signal strength is a simple function of distance
6: Each packet is transmitted at the same bit-rate

Figure 7: The probability of losing a packet to a quadrant within the field.
Accuracy of the Simulators

- Flooding algorithm

Benefits of Testbeds

- Allow a level of control over real world
- Use of real devices
- Real layer interaction with the OS
- Some provide a level of scaling
- Remote management
- Ability to run real applications

Introduction to Testbeds

- Emulab / Netbed
- ORBIT
- WHYNET
- APE

Disadvantages of Testbeds

- Repeatability
- Scaling
- Mobility of nodes
- Dependant on location
Emulators

- Emulators are a middle ground between pure simulation and wireless testbeds
- Combine the repeatability, configurability, isolation and manageability of simulations and the realism of testbeds
- Utilize a real MAC layer, provide a realistic physical layer
- Avoid adopting a uncontrollable or locale-specific architecture
- High degree of control and fidelity
  - Can use statistical models of signal propagation
  - Can replay traces of observed signal propagation
  - Can analyze behavior in artificial situations that would be hard to create in the real world.
- PROPSim, Tas4500 flex5 (Spirent Communications), CMU Emulator

Other Testbeds

- Netbed
  - 5 Motes, 5 Stargates on 5 robots, 25 static Motes, 23 wireless PCs
- APE (Ad hoc Protocol Evaluation)
  - "Virtual Mobility" metric, scenarios included
- WHYNET
  - CDMA 2000 cellular IP, Ultra Wideband, MIMO, Software Defined Radios

Emulator Architecture

- Number of RF nodes connected to emulator through cable attached to antenna port
- RF signal transmitted mixed with LO, digitized, and fed to DSP engine, composed of FPGAs
- DSP engine models effects of signal propagation (attenuation, fading)
- Combine all signals and send out though antenna port
Implementation

- Proof of Concept Prototype
  - Hardware [Laptops, A/D and D/A Boards, Wireless Cards]
  - DSP Engine [FPGA with delay pipes]
  - Emulation Controller [Script mode and Manual Mode]

- Validation
  - Fidelity
    - Physical Layer
    - EVM for signal vectors
    - Transport Layer
      - TCP throughput comparisons
  - Isolation

Signal Propagation Modeling

- Large Scale Path Loss
- Small Scale Fading
- Ray Tracing
- Capturing and Replaying Signal Behavior
- Channel Sounding

- Capabilities & Limitations of the model
  - Better at time granularity and fidelity than simulators
  - Easily expandable to support emerging technologies [MIMO, steerable antennas, time reversal]
  - Uses discrete elements to model, vis-à-vis continuous wireless phenomena
  - Multipliers in FPGA limits scale as complexity for interaction -> \( n^2 \)

Experiments

- Physical Layer Impact
  - Hidden Terminal Problem
    - RTS/CTS has huge overhead
    - It fails to prevent rate fallback
  - External Interference
    - Interfering Bluetooth source
    - Yagi Antennas are better

- Benchmark Experiments
  - Behavior of 5 cards, exact same models
    - NIC Signal Measurement
    - NIC Delivery Rate Variation
    - Multipath Performance

Rate Selection Algorithms

- Wireless Protocols have to tradeoff between throughput and range

- Three Techniques
  - ARF (Automatic Rate Fallback)
    - Uses in-band probing with 802.11’s ACK mechanism, more than necessary
    - Sets thresholds to increase and decrease transmission rates
  - SNR
    - Select optimal Transmission rate for a given SNR; adv is speed
    - Ignore multipath interference and measure SNR only at the receiver
  - ERF (Estimated Rate Fallback)
    - Hybrid Algorithm which combines best of both ARF and SNR
    - Run both in Parallel, then select apt estimate. Run SNR until multipath is detected or SNR is near decision threshold.
    - Very important at full capacity
Comparison

- Fixed RSS
  - SNR best, ERF close behind, ARF performs badly at intermediate signal levels
- Multipath
  - SNR sends at constant rate at 11Mbps, so performs very badly
- Fast Fading
  - Drive by scenario
  - ERF performs consistently
- These tests are very fine grained as compared to real world scenario increase

Final Thoughts / Questions

- Simulations lack environment details which vary results
- Simulators could provide tools to include environment details
- Simulator comparisons, but no accuracy comparisons
- Emulators are not a complete replacement
- Simulation required for large scale experiments
- Real world experiments required for fidelity or verification

References

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