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DESIGNING RESILIENCE IN TRANSPORT PROTOCOLS

PROPOSAL FOR PH.D. DISSERTATION RESEARCH

Overview

- Introduction and Motivation
- Related Work
- Proposed Research
- Preliminary Results

Overview

- Introduction and Motivation
  - Communication Networks & Challenges
  - Related Disciplines
  - Cross-Layering
  - ResiliNets Architecture
  - PoMo Architecture
- Related Work
- Proposed Research
- Preliminary Results

Communication Networks

- Are pervasive in our society
- Used for daily communication
- Trusted with livelihoods, finances, and health
- Control essential services: power grid, EMS
- An increasingly attractive target for attacks

Challenges

- Unusual but legitimate traffic
- Wireless channel conditions
  - Bit errors
  - Intermittent & episodic connectivity
- Resource limitations of mobile nodes
- Attacks
- Misconfiguration
- Natural Faults

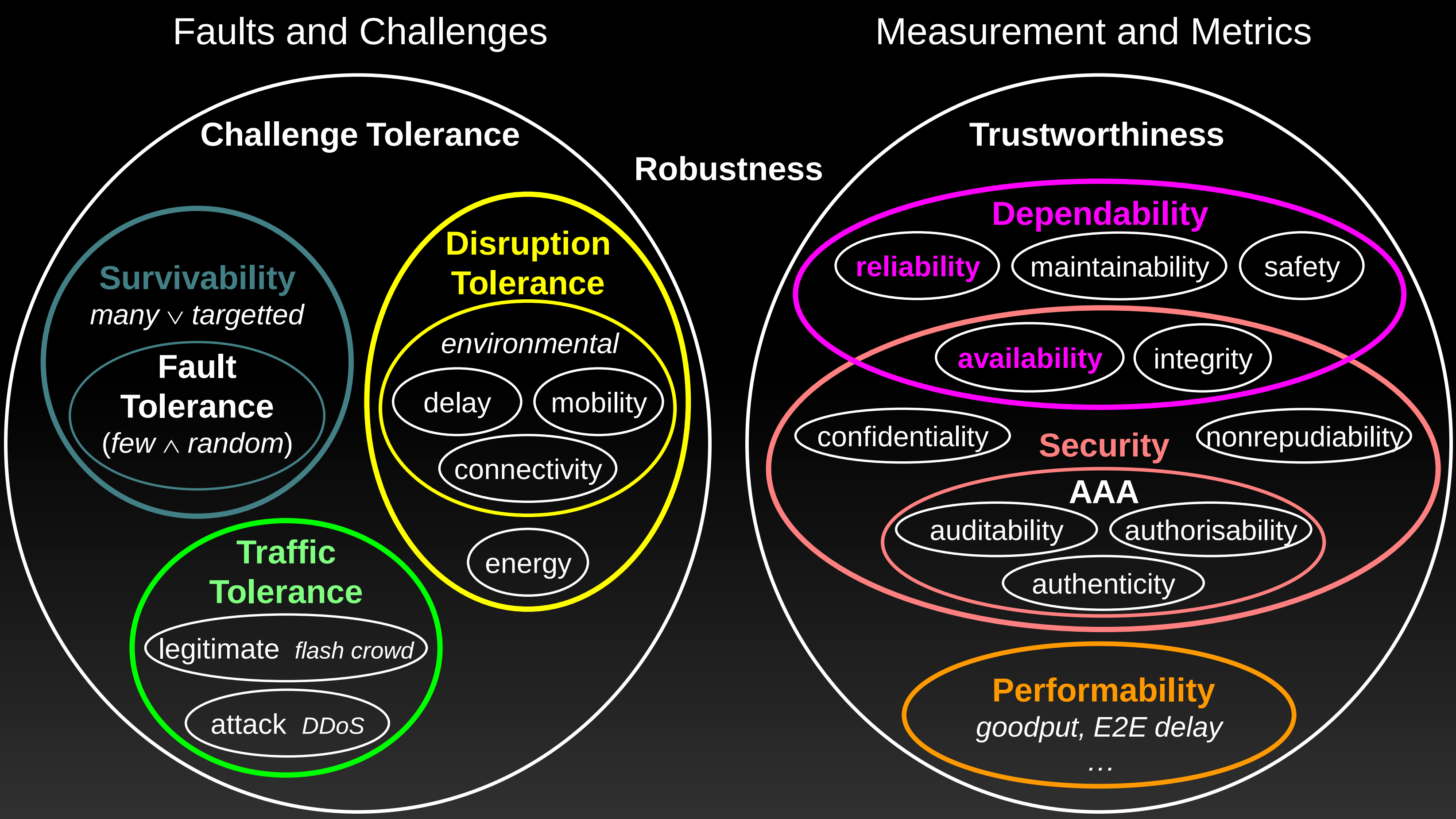
Disciplines

- Fault Tolerance (few, random)
- Survivability (many, intelligent)
- Dependability
  - Availability (instantaneous)
  - Reliability (long-term)
- Disruption Tolerance (interrupted connectivity)

Resilience

- Defined as: "The ability of the network to provide and maintain an acceptable level of service in the face of various faults and challenges to normal operation."
- By implication, Resilience is a superset of FT, Survivability, Dependability, and Disruption Tolerance

Scope of Resilience



Credit: [ResiliNets Group]

Cross-Layering 1

- Needed to support resilience
- Knobs influence behavior (e.g. FEC)
- Dials expose characteristics (e.g. BER)
- In band (header fields)
- Out of band (explicit signaling)
- NOT saying to throw away layering
  - Translucency principle

Cross-Layering 2

- Explicitly avoided in current Internet
- Implicitly essential to TCP
  - TCP infers congestion based on packet loss
  - RED based on this
- Implicit cross-layering insufficient
  - TCP assumes congestion for any loss event
  - Results in poor performance and inefficiency

ResiliNets Architecture

- Architecture for designing resilient networks
  - Motivational
  - Guides design
- Four Axioms
- Six-step Strategy D^2R^2+DR
- 18 Principles

ResiliNets Architecture

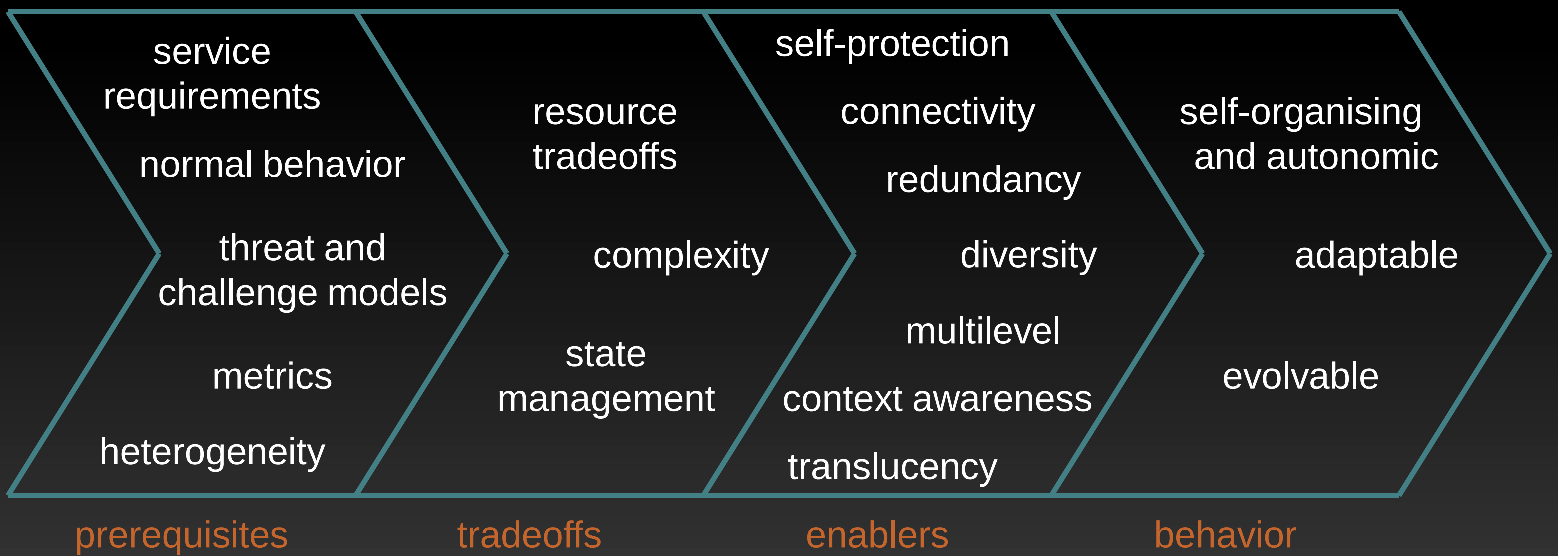
- Four Axioms
  - Inevitability of Faults
  - Understand Normal Operations
  - Expect Adverse Events and Conditions
  - Respond to Adverse Events and Conditions
- Six-step Strategy D^2R^2+DR
- 18 Principles

ResiliNets Architecture

- Four Axioms
- Six-step Strategy D^2R^2+DR
  - Real-time
    - Defend
    - Detect
    - Remediate
    - Recover
  - Background
    - Diagnose
    - Refine
- 18 Principles

ResiliNets Architecture

- Four Axioms
- Six-step Strategy
- 18 Principles

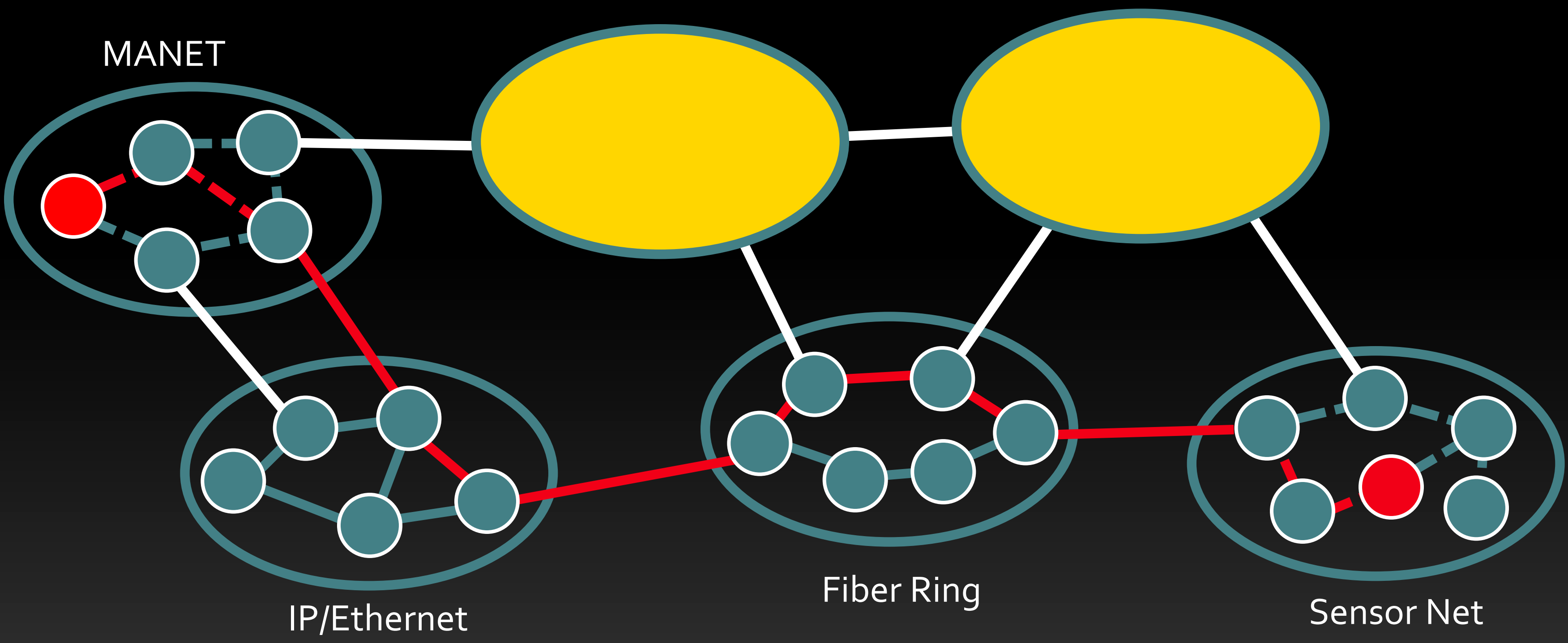


Credit: [ResiliNets Group]

PoMo Architecture

- Needs/enables x-layer transport layer
- PoMo: Postmodern Internetwork Architecture
- Funded by NSF under FIND program
- Thin internetwork layer (3.5)
- Enables heterogeneous internetworking
- Uses knobs and dials for cross-layering

PoMo Model



Thesis Statement

end-to-end communication
with resilience as an inherent design property
is necessary to meet
specified service requirements
in the face of various attacks and challenges

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  - Disruption Tolerant Networking
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Related Work

- Transport Protocols
  - 4th layer of OSI model
  - Lowest level of end-to-end communication
  - Ideal service:
    - Zero delay
    - Zero errors
    - Infinite bit rate
  - Still working on achieving ideal service

Related Work

- Transport Protocols
  - General purpose
    - UDP
    - ISO-TP (TP0-TP4)
  - Application specific
    - RTP
    - NETBLT
  - TP++
  - TCP and derivatives
- Disruption Tolerant Networking

Related Work

- Transport Protocols
  - Flexible and composable, e.g. TP++
    - 3 traffic classes
    - ARQ for bit errors & congestion loss
    - FEC for congestion loss
  - TCP and derivatives, e.g. SCPS-TP
    - Error notification
    - Outage notification
    - Rate based flow control

Related Work

- Transport Protocols
- Disruption Tolerant Networking
  - Challenged network types
    - Terrestrial Mobile Networks
    - Exotic Media Networks: satellite, acoustic, LOS
    - MANET & Military Ad-Hoc
    - Sensor Networks
  - TCP for Space
  - Bundling protocols

Related Work

- Transport Protocols
- Disruption Tolerant Networking
  - Challenged network types
  - TCP for Space
    - TCPSat
    - SCPS-TP
  - Bundling protocols
    - IPN
    - DTNRG

Problem Statement

- Resilience not explicitly addressed in TP design
- Fixed error control mechanisms
- Minimal adaptability
- Connection state too fragile
- Limited or no explicit cross-layering
- No support for multipath

Overview

- Introduction and Motivation
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  - Architecture and Design
  - 4-phase research plan
- Preliminary Results

Proposed Research

- Protocol Architecture and Design
  - Resilience Measures
  - Cross-Layering
  - Operational Modes (continuous or discrete)
- Research Plan
  - Resilience Principle Application
  - Algorithm Development
  - Simulation
  - Implementation

Proposed Research

- Protocol Architecture and Design
  - Resilience Measures
    - Metrics to characterize resilience of system
    - Work in progress by Abdul Jabbar
  - Cross-Layering
    - Knobs influence operation of lower layers
    - Dials pass info to higher layers
  - Operational Modes (continuous or discrete)
    - Multidimensional map accounting for network state and application needs

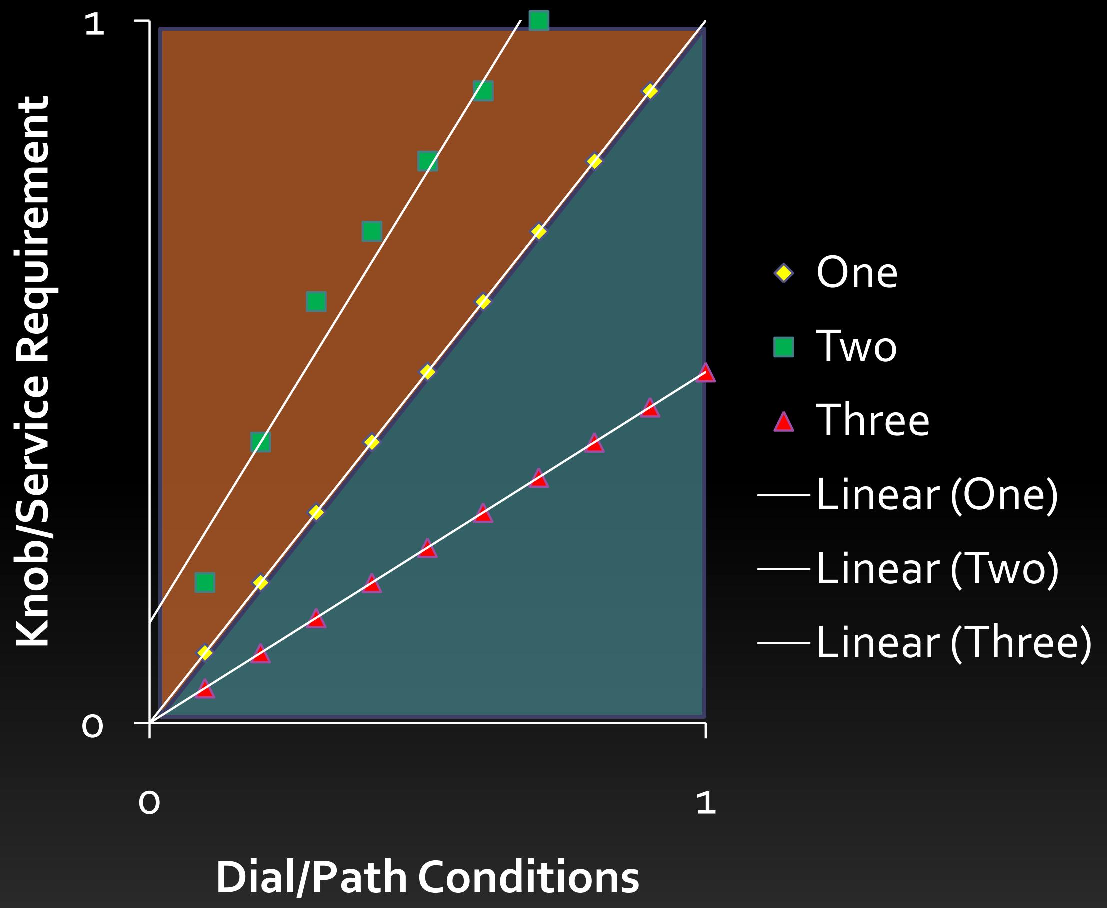
Proposed Research

Operational Modes

Requirement > Path capability

Path capability > Requirement

Can trade abundant resource for scarce (e.g. sacrifice bandwidth to reduce bit errors with FEC)

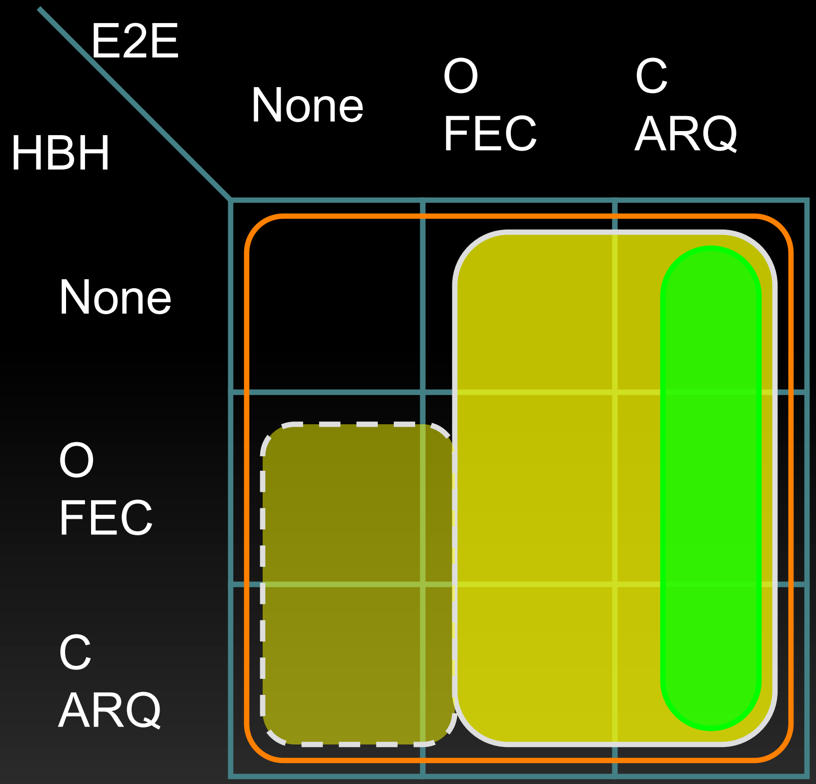


Proposed Research: Error Control Mechanism Tradeoffs

- Error Detection alone
  - Trades bandwidth for error detection
  - Open Loop
- FEC
  - Trades bandwidth for error correction
  - Open loop
- ARQ
  - Trades latency for error correction
  - Closed loop

Proposed Research: Error Control

- Error Control Example
- Alternatives
  - N: none
  - O: open loop (FEC)
  - C: closed loop (ARQ)
    - S&W, GB-N, SelRep
- Location
  - HBH
  - E2E
- App requirements
  - unreliable
  - quasi-reliable
  - reliable



Credit: [James P.G. Sterbenz & David Hutchison]

Proposed Research: Mechanisms

- Error Control
  - FEC and/or ARQ
    - E2E or HBH?
  - Explicit Congestion Notification (ECN)
  - Explicit Corruption Notification
    - Recoverable
    - Unrecoverable (ELN)
  - Explicit Outage Notification (EON)
  - Explicit Delay Notification (EDN)

Proposed Research: Mechanisms

- Multipath
  - Present given resilient topology (≥bi-connected)
  - Requires multipath routing
  - What to do and where to do it?
    - Transport layer or Network layer?
  - Aggregate bandwidth
  - Erasure Coding
- Geographic Diversity
  - Benefits of multipath + survivability

Proposed Research

- Research Plan
  - Phase 1: Resilience Principles
    - Service requirements, threat and challenge models, context aware, multilevel resilience, redundancy and diversity, resource tradeoffs
  - Phase 2: Algorithm Development
    - Explore interactions and tradeoffs of mechanisms
    - ECN, ELN, EON, EDN
    - Open and closed loop flow control

Proposed Research

- Research Plan
  - Phase 3: Resilient Transport Simulation
    - ns-2: open source, widely used
    - Experiment with mechanisms from phase 2
    - Challenge scenarios
    - Wired, MANET, and sensor realms
  - Phase 4: Resilient Transport Implementation
    - Validate simulation models from phase 3
    - Analyze real-word effects
    - Wired, MANET, & sensor realms

Research Contributions

- Theory
  - Service Requirement to Path State relationship
    - How do knobs and dials relate in multidimensional space?
    - How does this relate to metrics space?
  - Tradeoffs
    - Between layers
    - Within E2E layer
- Functional
  - Simulation models
  - Transport protocol implementation

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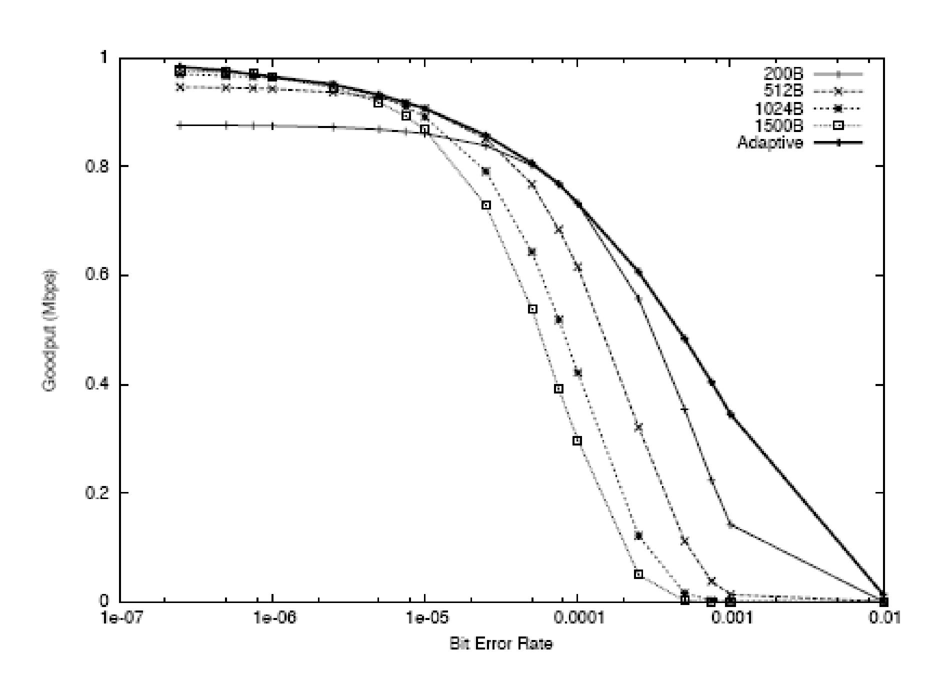
  - Packet size adaptation
  - Cross-layer ns-2 architecture
  - PoMo E2E cross-layer framework

Preliminary Work

- Packet Size Adaptation
  - Simulation code to verify mathematical model
- Cross-layer Architecture for Simulation
  - Data structure in ns-2
- PoMo E2E Cross-Layering Framework

Preliminary Work

- Packet Size Adaptation
  - Selects optimal packet size given header length and BER
  - 4 fixed-size curves
  - Adaptive curve forms envelope of fixed-size curves



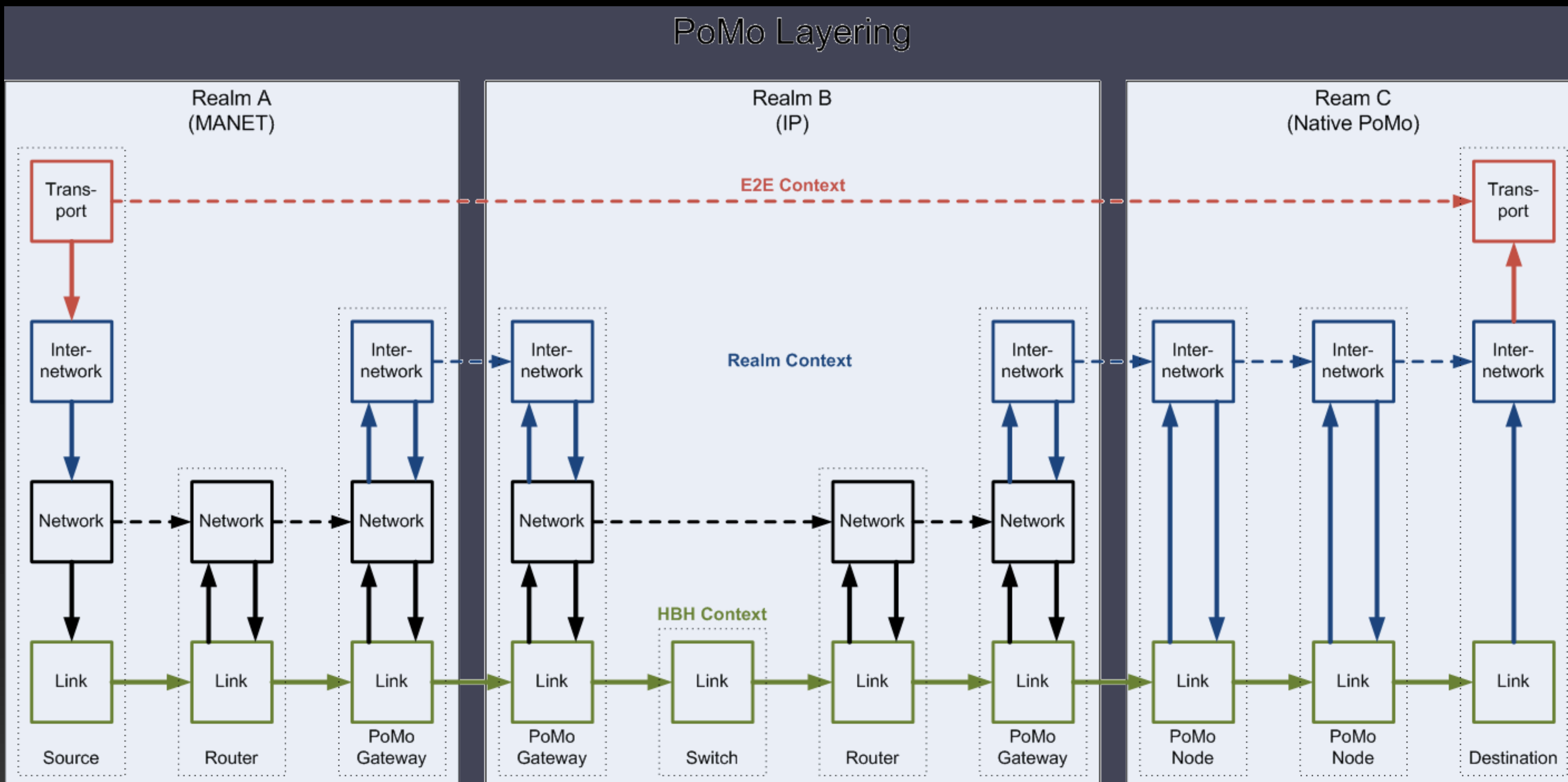
Credit: [Sarvesh Varatharajan]

Preliminary Work

- Packet Size Adaptation
- Cross-layer Architecture for Simulation
  - No packet content in ns-2 simulations
  - Need data structure to store knobs/dials
- PoMo E2E Cross-Layering Framework

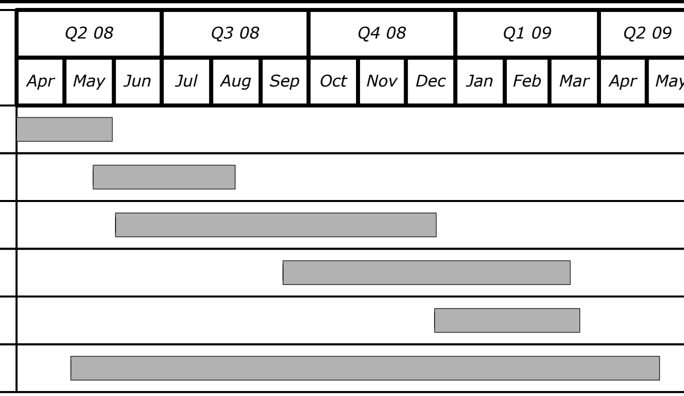
Preliminary Work

PoMo E2E Cross-Layering Framework
Realms communicate via PoMo layer
Provides standardized cross-layering interface



Timeline and Milestones

ID	Task Name	Start	Finish	Duration
1	Principle Application	7/2/2007	5/30/2008	48w
2	Algorithm Development	5/19/2008	8/15/2008	13w
3	Simple Simulations	6/2/2008	12/19/2008	29w
4	Implementation	9/15/2008	3/13/2009	26w
5	Complex Simulations	12/19/2008	3/19/2009	13w
6	Dissertation Writing	5/5/2008	5/8/2009	53w



Questions

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