Dependable Future Mobile Networked Systems:
Connected Communities, Vehicles & Health

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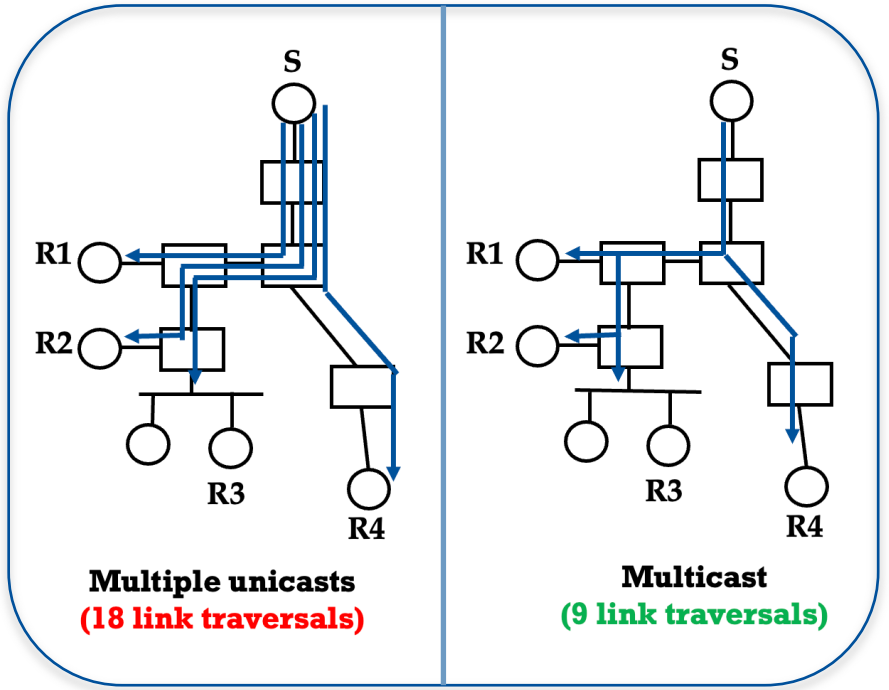
Network Design Evolution: Multicast Routing Example

- Network Protocol Design : IP Multicast [Group Routing]
  - Protocol Independent Multicast (*PIM*)[1]: '94 – '04, 50+ spec iterations
- Goals: loop-freedom, efficient delivery (low loss & duplication)
- Challenges:
  Group membership dynamics – network failures, configurations – arbitrary topologies
- Approaches:
  - Simulations with test-suites (***NS-2***)[2] for ***average case*** analysis
  - ***STRESS***[3] analysis for ***breaking points***
- Issues:
  - State space explosion, topology synthesis, fault modeling & injection, scaling
  - Breaking points vary with different spec versions (50+), need automation



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New Generations of Mobile Networks

- Just when it was complex, mobility comes along!
  - Infrastructure-less self-configuring networks
- Evolution of mobile & Behavior-based networks
  - Ad hoc networks '96 – Wireless sensor networks '03 – Delay/Disruption Tolerant Networks (*DTNs*) '07
  - Internet of Things (*IoT*) – Location-based Services – Cyber Physical Systems (*CPS*)
- Smart Cities & Communities
  - Computational health, connected wellness
  - Shared transportation (ride & car sharing)
  - Vehicular networks …
- City-wide sensing, crowd sourcing
  - Participatory & opportunistic networks
  - Environmental sensing
  - Real time traffic and road conditions
  - Public Safety …

New Dynamics & Models: Adding Mobility to the Mix

- People & mobile devices *are the network*!
  - Humans in the net & in the loop
- Network topology dynamics are part of normal operation, not the exception
  - Revisit the concept of routing & connectivity
- ***Mobility modeling*** essential in design and evaluation of networks[4,5,6]
  - Need rich set of mobility models that span dimensions of ***space*** of interest
  - Data-driven mobility is needed for realism
- Use of ML for accurate (mobility) models and inform protocol design[7,8]
  - Collected 70+ TB of mobility and traffic data over 20+ years '03 – current
  - ***Data-driven*** design and analysis
  - GANs and VAEs used for generative modeling
  - Clustering techniques and similarities used for design of services

Future Network Challenges

- Identifying breaking points for dynamic unexplainable networks?
  - ML is adaptive, self-configuring
  - System, obj. fn, data → embedding in latent/hidden feature space → optimal solution
    - Data damage: noisy, mislabeled. Can we '***unlearn***'/reverse bad steps?!
    - Explainability and bias issues …
- State space coverage
  - Multi-dimensional data & feature spaces
  - Miles in AVs vs richness of scenarios in the data

Future Network Challenges (cont.)

- Building on unreliable blocks
  - Use of chatGPT, block chain & variants, in networked pipelines & combinations
  - Need systematic automatic tools for frequent dependability evaluation of blocks
- Human in the loop, unpredictable behavior
  - How to account for human behavior in dependability?
  - Unintended consequences on society
- Need multi-disciplinary approaches[9]
- Main Challenging Frontier:
  - Connected health, precision medicine, bioTech

Select References on Net Protocols & Mobility Modeling:

1. D. Estrin, D. Farinacci, **A. Helmy**, D. Thaler, S. Deering, V. Jacobson, M. Handley, C. Liu, P. Sharma, L. Wei, "Protocol Independent Multicast - Sparse Mode (*PIM-SM*): Protocol Specification" ver. 2, *RFC 2362 of the Internet Engineering Task Force (IETF), Inter-Domain Multicast Routing (IDMR) Group*, June 1998.
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… more at: sites.google.com/uncc.edu/helmy/ (being updated!)