# Future (International) Internet Research

Darleen Fisher

dlfisher@nsf.gov

SwitchOn Workshop

January 8, 2015

# Outline of Talk

- Future Internet Architectures (FIA)– a Case Study
- Hitting the Trends
- Leveraging the Enablers
  - Technologies
  - Research Infrastructures
- Exploring the Environment(s)
- Finding the Confluences
- Making it Matter
- FIA – Reprise

# Future Internet Architectures

- NSF's Perspective—Challenge to research community to design a secure full-functioning Internet that meets the needs of the 21st century
  - Bold architecture research
  - Fostering innovative systems research
- 10 Year Endeavor—Three Phases
  - Components (FIND)
  - Architectures (FIA)
  - Systems building and application to environments (FIA-NP)

→ Deep Understanding of Current Internet and Design Tradeoffs

→ Network Designs with Full "Internet" Functionality

→ Research Community Focusing on Innovative, Big Systems/Architecture Design & Implementation

→ Integration of Big Systems and Security

→ Collateral Innovative research ideas

# Future Internet Architectures

- MobilityFirst
- Named Data Network (NDN)
- NEBULA
- eXpressive Internet Architecture (XIA)

# MobilityFirst

RUTGERS
(LEAD)

D. Raychaudhuri, W. Trappe,
R, Martin, Y. Zhang, I. Seskar

A. Venkataramani, (J. Kurose), P. Shenoy

Duke
UNIVERSITY

X. Yang

THE UNIVERSITY of WISCONSIN
MADISON

S. Bannerjee

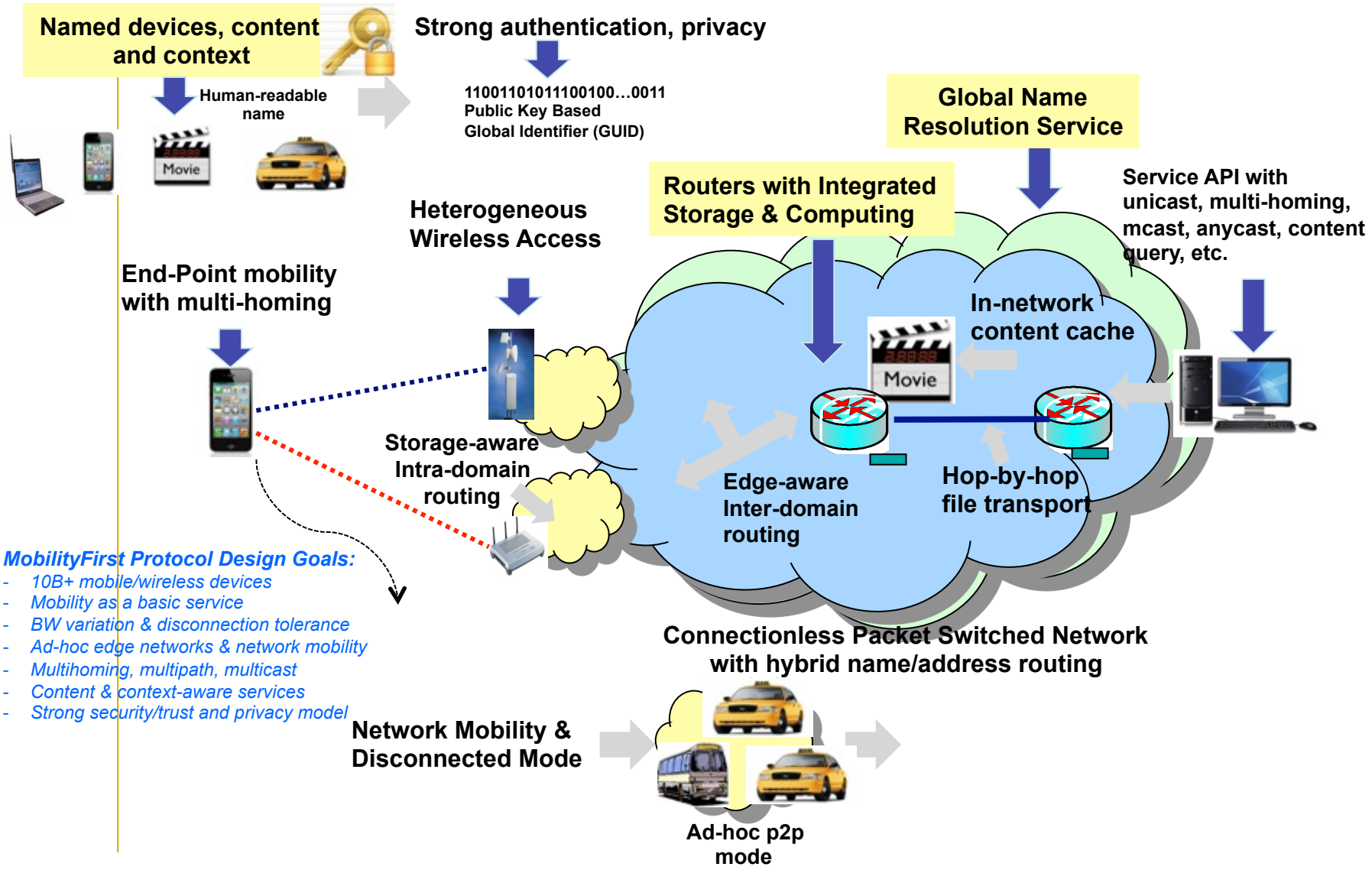
University of Nebraska Lincoln

B. Ramamurthy

Z. Morley Mao

W. Lehr

# MobilityFirst Concepts: Architecture Summary




***MobilityFirst Protocol Design Goals:***

- *10B+ mobile/wireless devices*
- *Mobility as a basic service*
- *BW variation & disconnection tolerance*
- *Ad-hoc edge networks & network mobility*
- *Multihoming, multipath, multicast*
- *Content & context-aware services*
- *Strong security/trust and privacy model*

# Named Data Networking Team

UCLA

Jeff Burke
Van Jacobson (architect)
Lixia Zhang

Colorado State University

Christos Papadopoulos

UCSD

Kim Claffy

UNIVERSITY OF MICHIGAN

Alex Halderman

ARIZONA

Beichuan Zhang

THE UNIVERSITY OF MEMPHIS

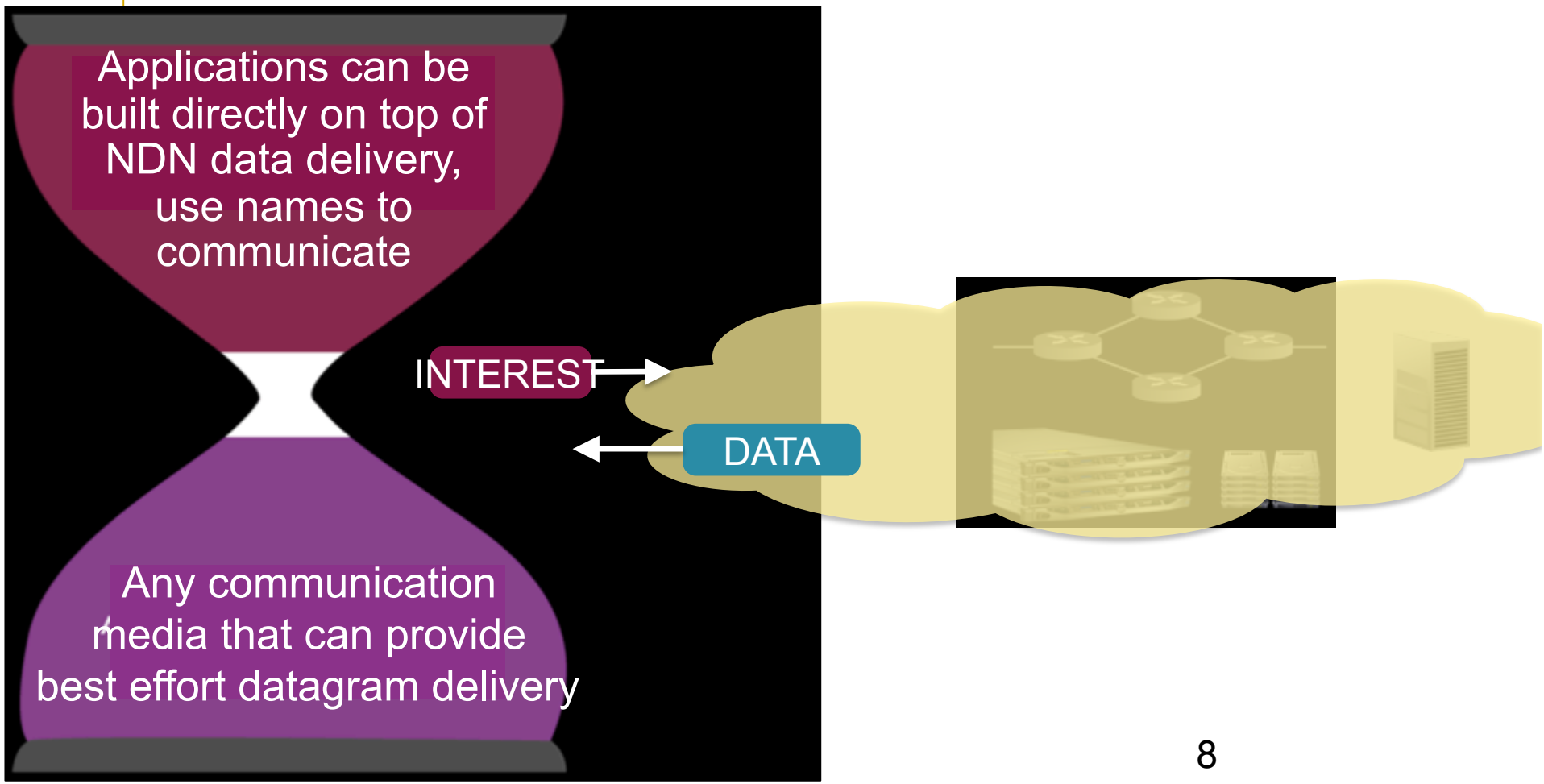
Lan Wang

ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Tarek Abdelzaher

Patrick Crowley

# The Basic NDN Architecture Concept



# NEBULA Future Internet

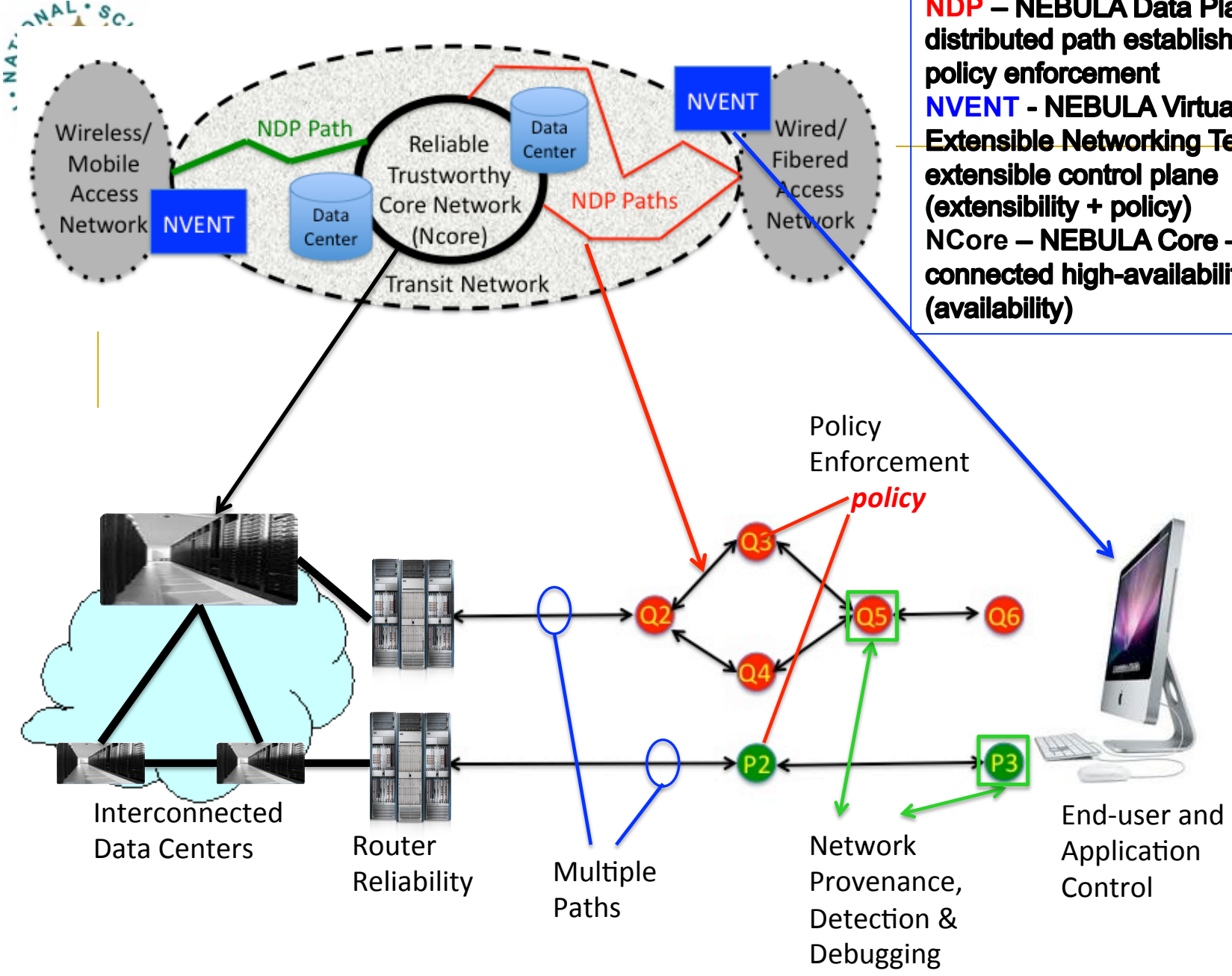
ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Massachusetts Institute of Technology

STEVENS
INSTITUTE of TECHNOLOGY
THE INNOVATION UNIVERSITY

PURDUE
UNIVERSITY

Cornell University




**NDP – NEBULA Data Plane – distributed path establishment and policy enforcement**
**NVENT - NEBULA Virtual and Extensible Networking Techniques – extensible control plane (extensibility + policy)**
**NCore – NEBULA Core – redundantly connected high-availability routers (availability)**

# The eXpressive Internet Architecture

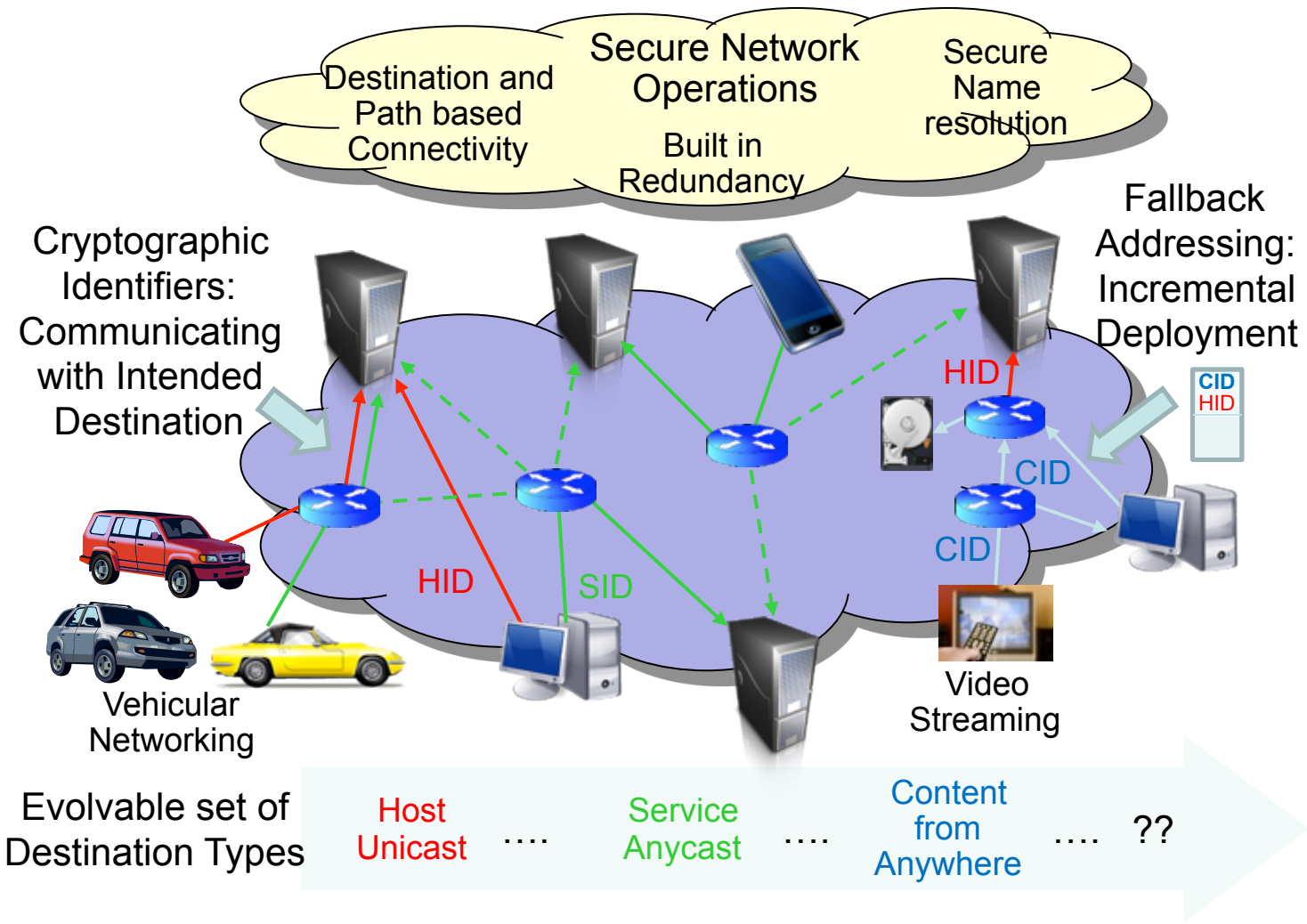
Peter Steenkiste, David Andersen,
David Eckhardt, Sara Kiesler,
Jon Peha, Adrian Perrig, Vyas Sekar,
Srini Seshan, Marvin Sirbu, Hui Zhang
Carnegie Mellon University

Aditya Akella, University of Wisconsin

John Byers, Boston University

Bruce Maggs, Duke University

# XIA Overview



# Finding Exciting Research Ideas

- Hitting the Trends
- Leveraging the Enablers
- Exploring the Environments
- Inviting Confluences
- Understanding the Problem
- Formulating a Potential Approach

# Hitting the Trends—Some Examples

- How is the Internet Changing? Where are the (New) Open Questions?
  - Explosion in Mobile Users and Networks
  - Increasing Priority of Content
  - Rise of Video Streaming (traffic different from web traffic) and Demand for Quality of Experience (QoE) Everywhere
  - Development & Deployment of Cyber-Physical Systems with Sensor and Actuators in Realtime
  - Future of Internet of Things (IoT)
  - Changing Structure of the Internet
    - Content Delivery Networks (CDNs) -- Caching and Data Centers
    - Internet Exchange (Ixes) & Software Defined Interconnects– Flattening of the Internet
    - Rise of clouds, cloud services,
      - Integration of clouds and networks (e.g. (mobile) wireless at the edge--clouds in the middle)
    - Increasing Virtualization and Federation
    - Potential Balkanization of Networks

# Hitting the Trends (cont.)

- Merger of Big Data + High Performance Computing + High Capacity Networks (e.g. Data Analytics)
- What are the Challenging Environments?
  - Critical Infrastructures (Power Grid, Airline Control systems, etc.)
    - (Researchers need access and real knowledge of the systems to work in this area)
  - Life-critical Cyber-Physical Systems (CPSs)
  - Underwater Networking
  - Networks for Drones
- What are Social Trends and What is their Potential Network Impacts?
  - Rise of On-line Social Networks, On-line Advertising, Crowd Sourcing, and Proliferation of Apps
  - Hacking and Nation State-Level Attacks
  - Loss of and Desire for Privacy; Rise of e-bullying; Potential Tracking /Stalking

# Leveraging the Enablers

What New Research Questions and Opportunities Opened by:

- Technologies, Software, and Resources such as:
  - OpenFlow
  - SDN Switches
  - Optical Devices (e.g. integrated photonic circuits)
  - Network Functions Virtualization (NFV)
  - IaaS, PaaS, SaaS, XaaS
  - OpenStack
  - Unlicensed Spectrum
  - Full-Duplex Massive MIMO
  - Pico Cells
  - Data
  - Others

→ What New Technologies are Needed?

- Research Infrastructures such as:
  - GENI, ORBIT, NSFCloud, Brazil's FIBRE, EU's (FIRE/Fed4FIRE) & Grid 5000, PlanetLab, ViCCi, ViNi, Emulab, Internet2, etc.
    - Virtualized and Federated

# Exploring the Environments—What are the Unique Challenges Here?

Examples:

- Body-Area Networks (Intra-body medical devices; wearables)
- Machine to Machine (M2M) networks
- Home Networks
- Crowds
- Business to Business (B2B) Networks
- Vehicular Networks
- Enterprise Networks
- Data Centers + High Performance Computing
- Clouds
- (Real-time) CPSs (Smart Grid Smart Health, etc.)
- Social On-Line Networks with Privacy Protection
- Video Delivery Systems

# Finding the Confluences

- Review George Varghese's 2014 SIGCOMM Keynote Slides!
  - Networking and Algorithms
  - Queuing and Networking
  - Economics and Networking
  - Networking and Virtualization
- Apply his ideas and cautions to open questions you see
  - Multiple  fields and areas of expertise
  - US-Brazil Perspectives and Strengths

# Exploring a Research Problem

- What is an open or new problem that if solved would make a significant difference?
- Can you conceive of a new approach to solve the problem? How would you get preliminary results that indicate potential success?
- Do you and your collaborators have the required expertise to do the work? If not who else do you need?
- How does your proposed work fit in with what has been done? Why/how is it more promising that others' work?
- How will you and others know that your completed work is successful? Can you conceive of an evaluation plan?
- Is the overall project "right-sized" for the problem/funding / project duration/PI + students involved?

# FIA--Reprise

- Trends– Mobility, Data/Content, Cloud as 24/7 Utility, Extensibility, Future Proofing
- Infrastructures—GENI, Orbit, Overlays, Special Purpose Equipment and Testbeds
- Technologies– SDN, DAGs, Serval, etc.
- Environments– Vehicular, Smart Buildings, Smart Health, Internet of Things (IoT), Video Services w/ QoE, Mobile Data Services Trial with a Wireless ISP, CDN Trial with PBS stations, Context-aware Public Service Weather Emergency Notification System
- Confluence – Built-in Security

# FIA projects asked and wrestled with (and you should too):

- What are the current and future big challenges?
  - Consider trends, technologies, requirements, etc.
- How to think outside the box, but not out in left field?
  - Be innovative, but also understand dissertation-size chunks, publication environments, and feasibility of use
- How to choose collaborations wisely?
  - Compatible Colleagues
  - Compatible Expertise
  - Team—only as big as the problem requires

# Thank you.