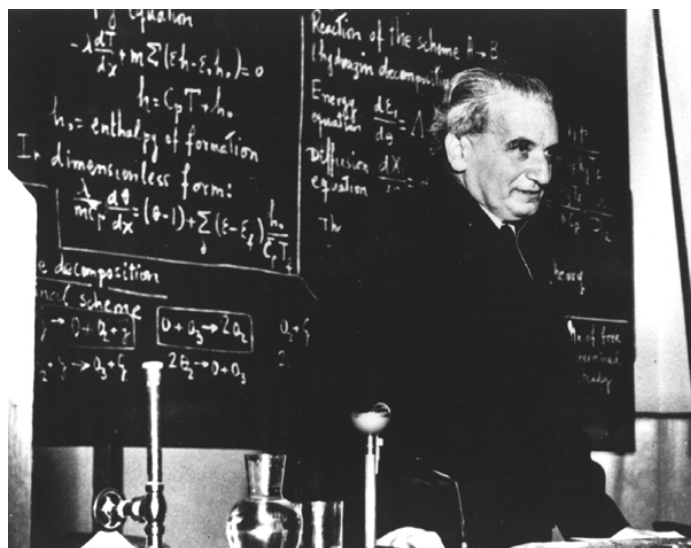
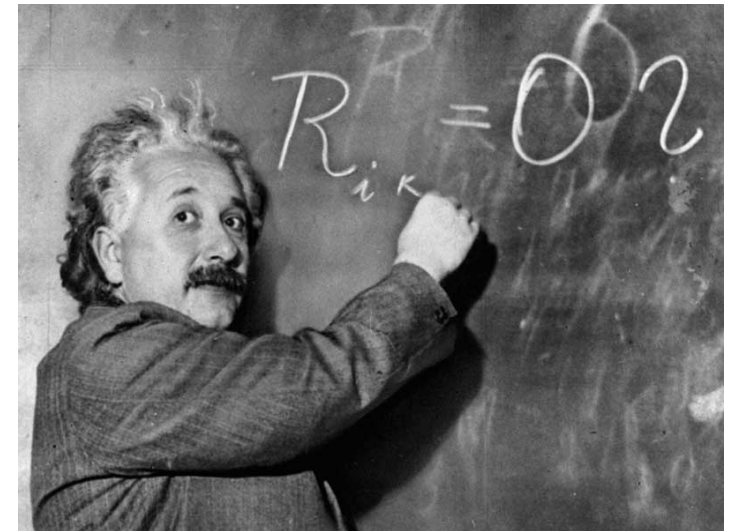


Distinguishing Between Connectivity, Intermittent Connectivity, and Intermittent Disconnectivity

Kevin C. Almeroth
UC-Santa Barbara
September 13, 2007

"I was originally supposed to become an engineer, but the thought of having to expend my creative energy on things that make practical everyday life even more refined, with a bleak capital gain as the reward, was unbearable to me."

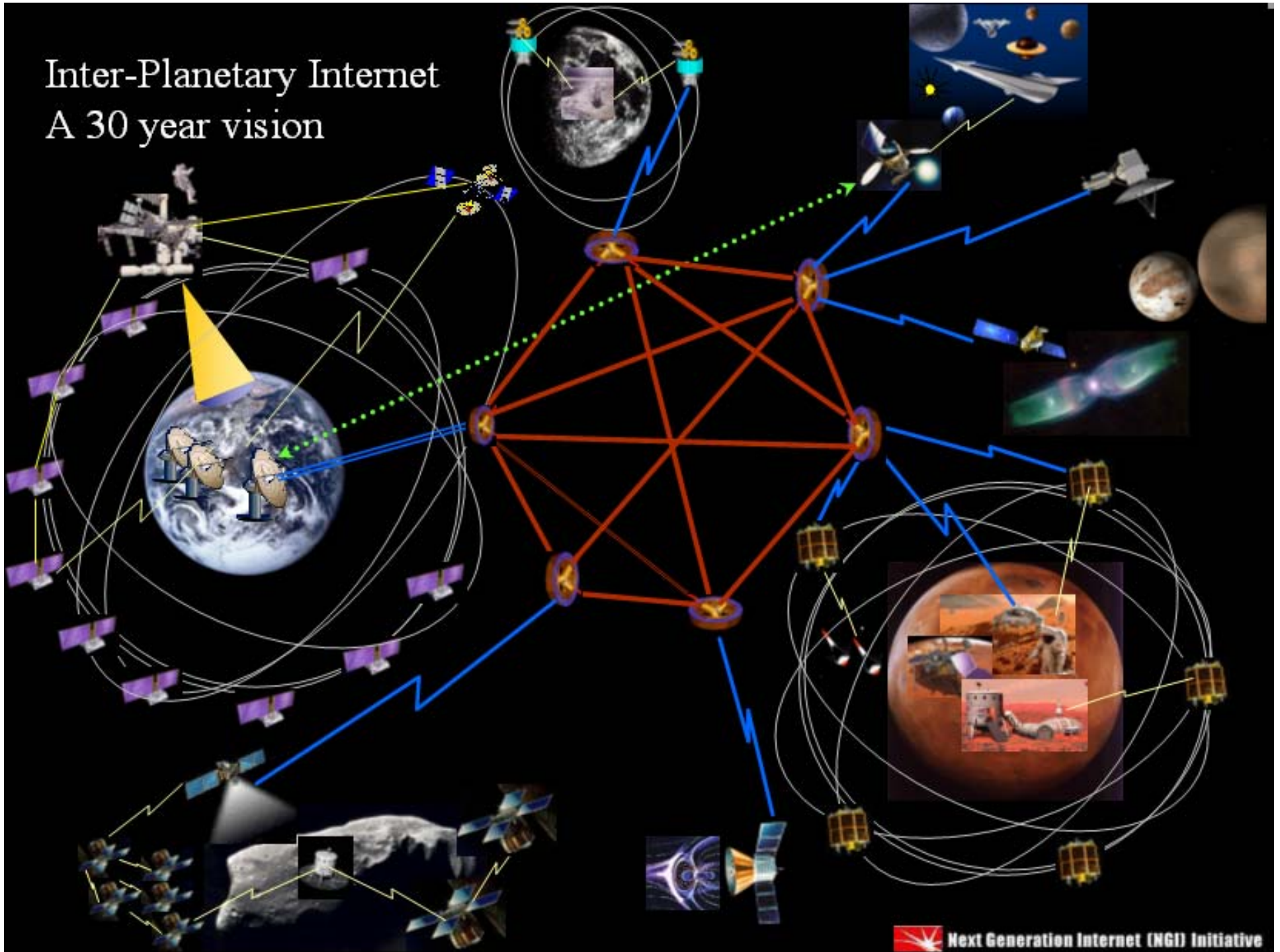
Albert Einstein to Heinrich Zangger, Aug. 11, 1918



"Scientists discover the world that exists; engineers create the world that never was."

Theodore von Karman

Inter-Planetary Internet A 30 year vision



Inter-Planetary

Mars rover tiptoes into giant crater

LOS ANGELES, California (AP) -- Two months after surviving a giant dust storm, one of NASA's robotic rovers on Mars began a risky drive Tuesday into a crater blasted open by a meteor eons ago.



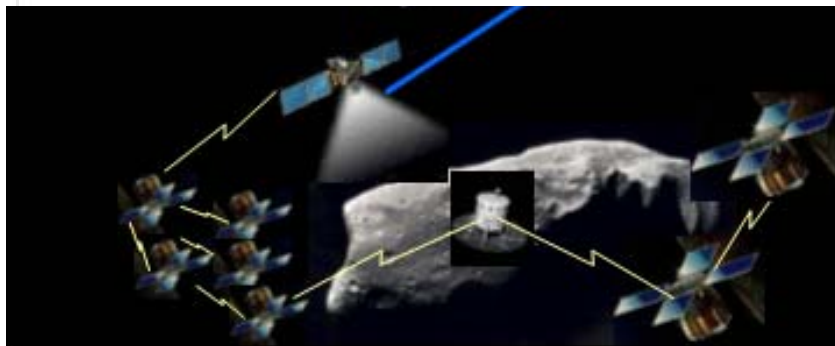
Scientists want the rover Opportunity to travel 40 feet down toward a bright band of rocks in the Victoria Crater. They believe the rocks represent the ancient surface of Mars and that studying them could shed clues on the planet's early climate.

On Tuesday morning, engineers sent commands to Opportunity to begin its journey, and the robot signaled a confirmation. **It will be several hours before scientists know how well the drive is going,** and the trek itself will take several days.

Opportunity's first task will be to "toe dip" into the crater, a move that involves rolling its six wheels below the rim and immediately back out to gauge its footing.

NASA/JPL-CALTECH

Opportunity looks out at Victoria Crater.



CNN.com /technology

updated 5:00 p.m. EDT, Tue September 11, 2007

 Next Generation Internet (NGI) Initiative

The First Round of “New” Assumptions

- Very large delays
 - RTT could range from milliseconds to days
- Intermittent/disconnected links and paths
 - End to end connectivity might “never” exist
 - Routers may need significant persistent storage
- High link error rates
 - Loss is due to corruptions, not congestion
 - RF interference, light or acoustic interference
- Heterogeneous underlying networks and protocols
 - Specialized networks move beyond IP, and run customized protocols

The Next Generation of Challenges

- Loss Rates (scintillation)
- Mobility
- Delay
- Storage
- Heterogeneous Network Paths
- Device Characteristics/Capabilities
- Topology
- Connectivity

The Spectrum of Connectivity Possibilities

Continuous
Connectivity

Autonomous
Operation



The Spectrum of Connectivity Possibilities

Continuous
Connectivity

Intermittent
Connectivity

Autonomous
Operation

Intermittent
Disconnectivity

Infrequent
Connectivity

The Spectrum of Connectivity Possibilities

Topology Variations



Continuous
Connectivity

Intermittent
Connectivity

Autonomous
Operation



Intermittent
Disconnectivity

Infrequent
Connectivity

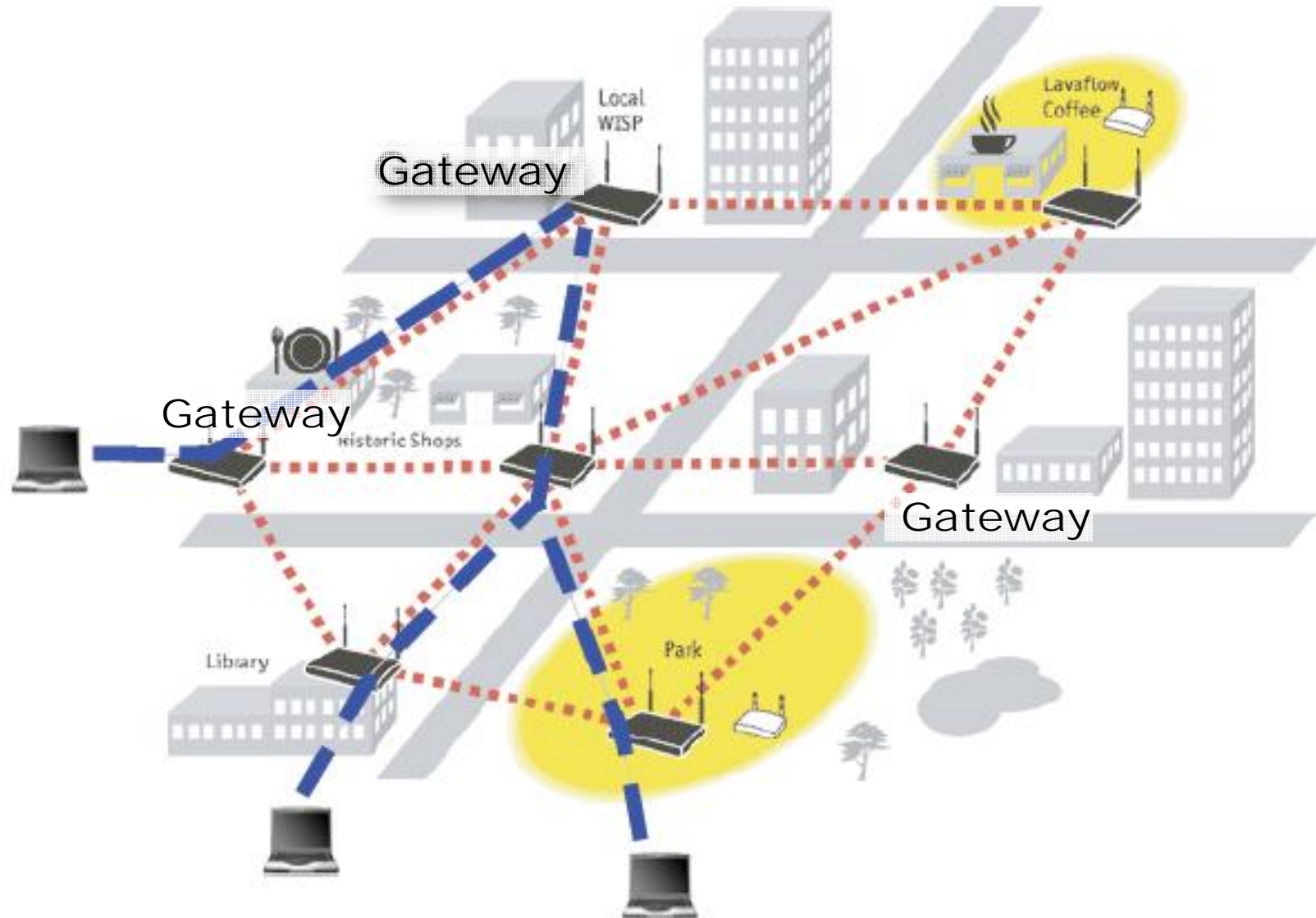


End-to-End Availability

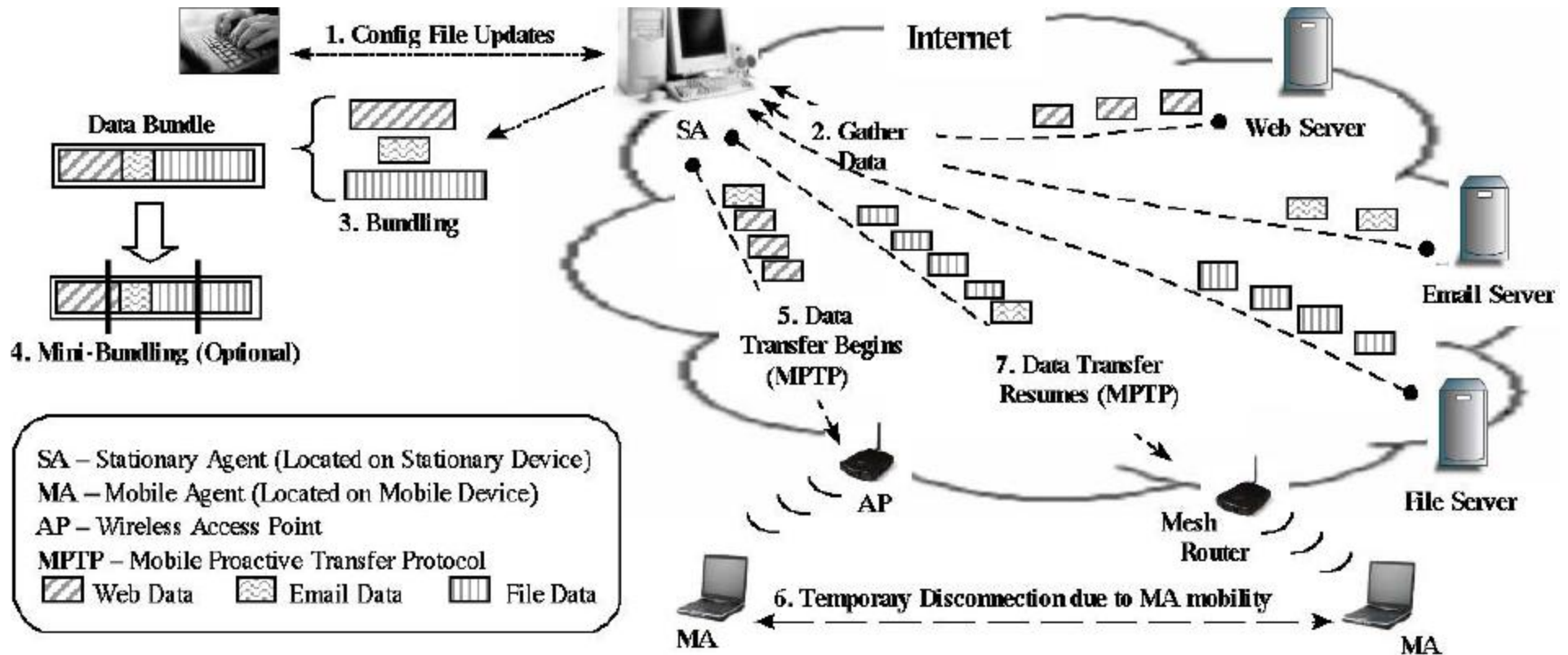
Some Interesting Ideas

- Multi-Hop Mesh Networks
- Data Bundling and Infrequent Connectivity
- Coupons
- ParaNets
- Disaster Recovery
- NSF Future Internet Network Design (FIND)
- Transformational Communication (TSAT)

Metro Mesh Networks

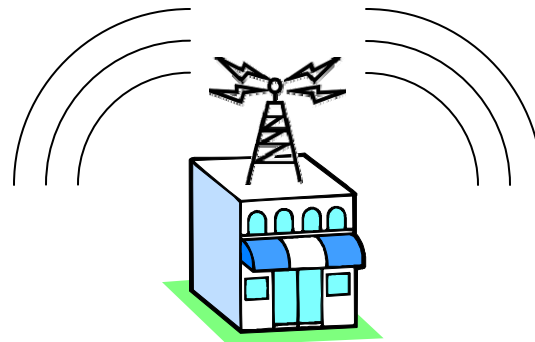


Infrequent Connectivity & Data Bundling



Coupons: Opportunistic Contact

- A “store” wants to advertise a “coupon”
 - basic information dissemination problem
 - technique: broadcast coupon periodically
 - challenge: wide but efficient distribution



Store

Coupons: The Basics

- Users passing the store receive the broadcast



User A



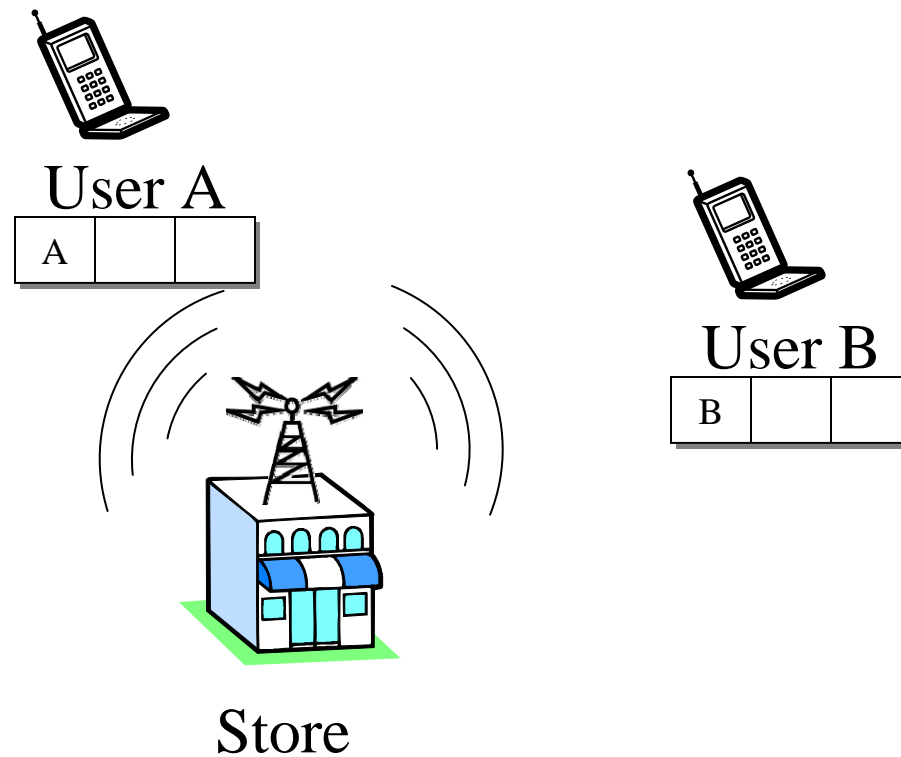
User B



Store

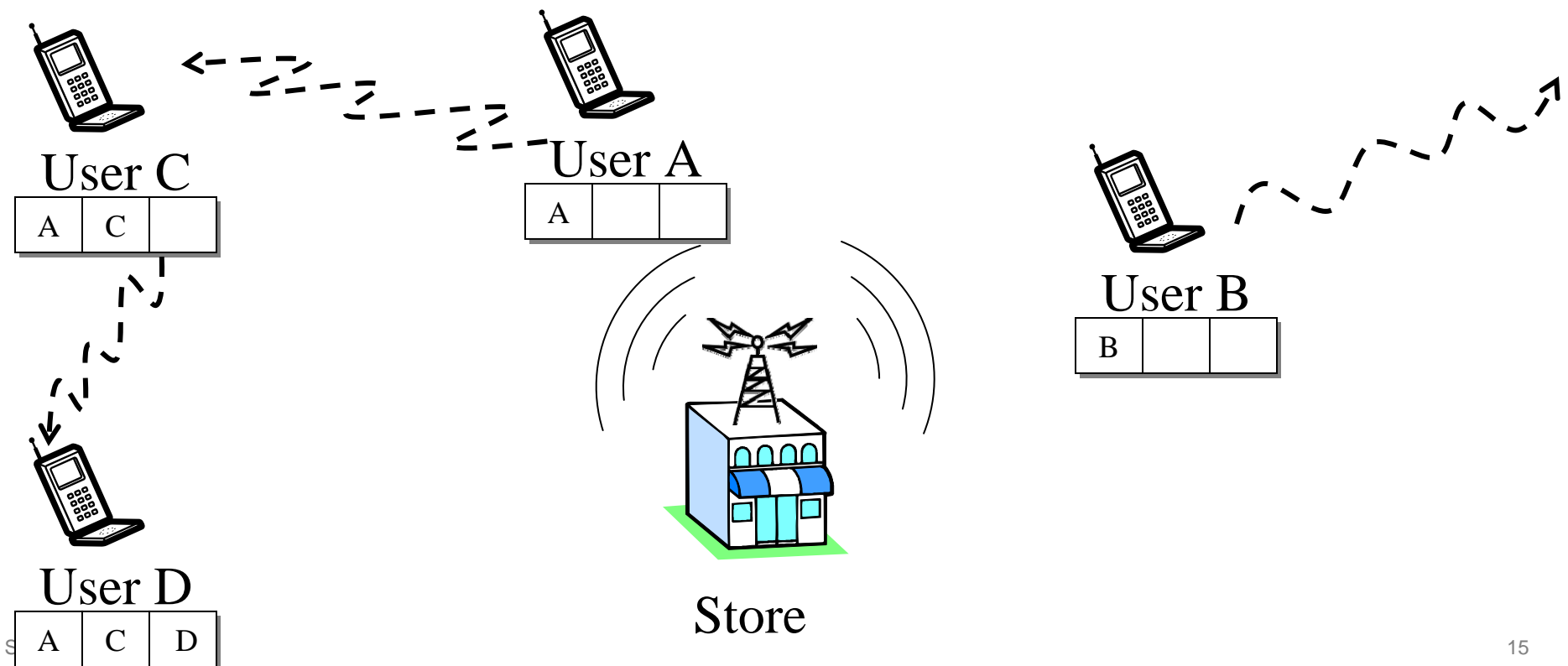
Coupons: The Basics

- Users who receive the “coupon” add their ID to a linked list



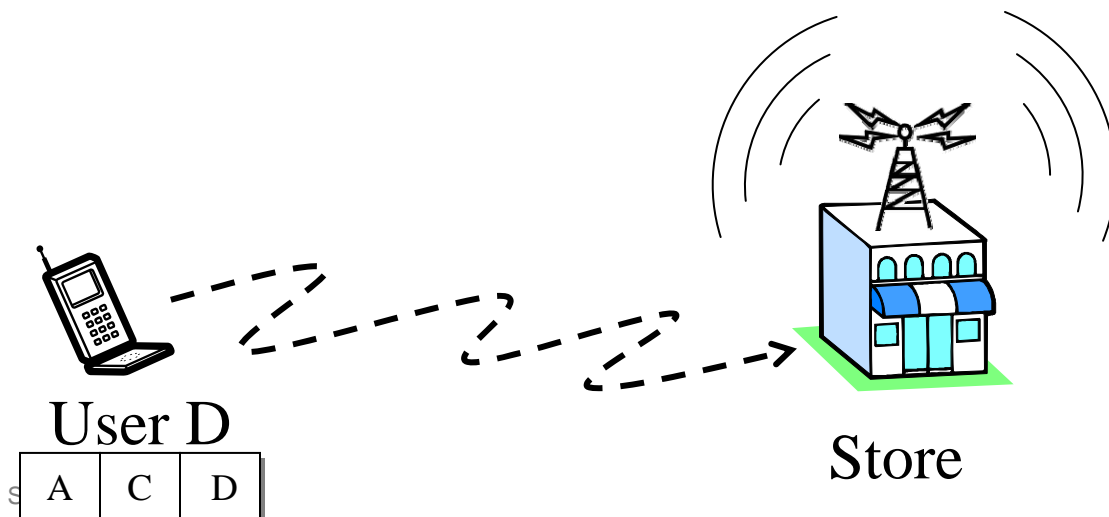
Coupons: The Basics

- Users then move and “infect” other users, who also add their ID to the end of the list



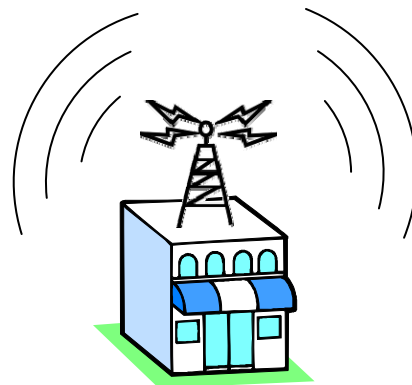
Coupons: The Basics

- At some point a user will return to the store and use the coupon



Coupons: The Basics

- Discount is divided among list members
 - Option #1: equal discount for all
 - Option #2: constant discount, divided equally among all of the list members
 - Option #3: weighted division of discount

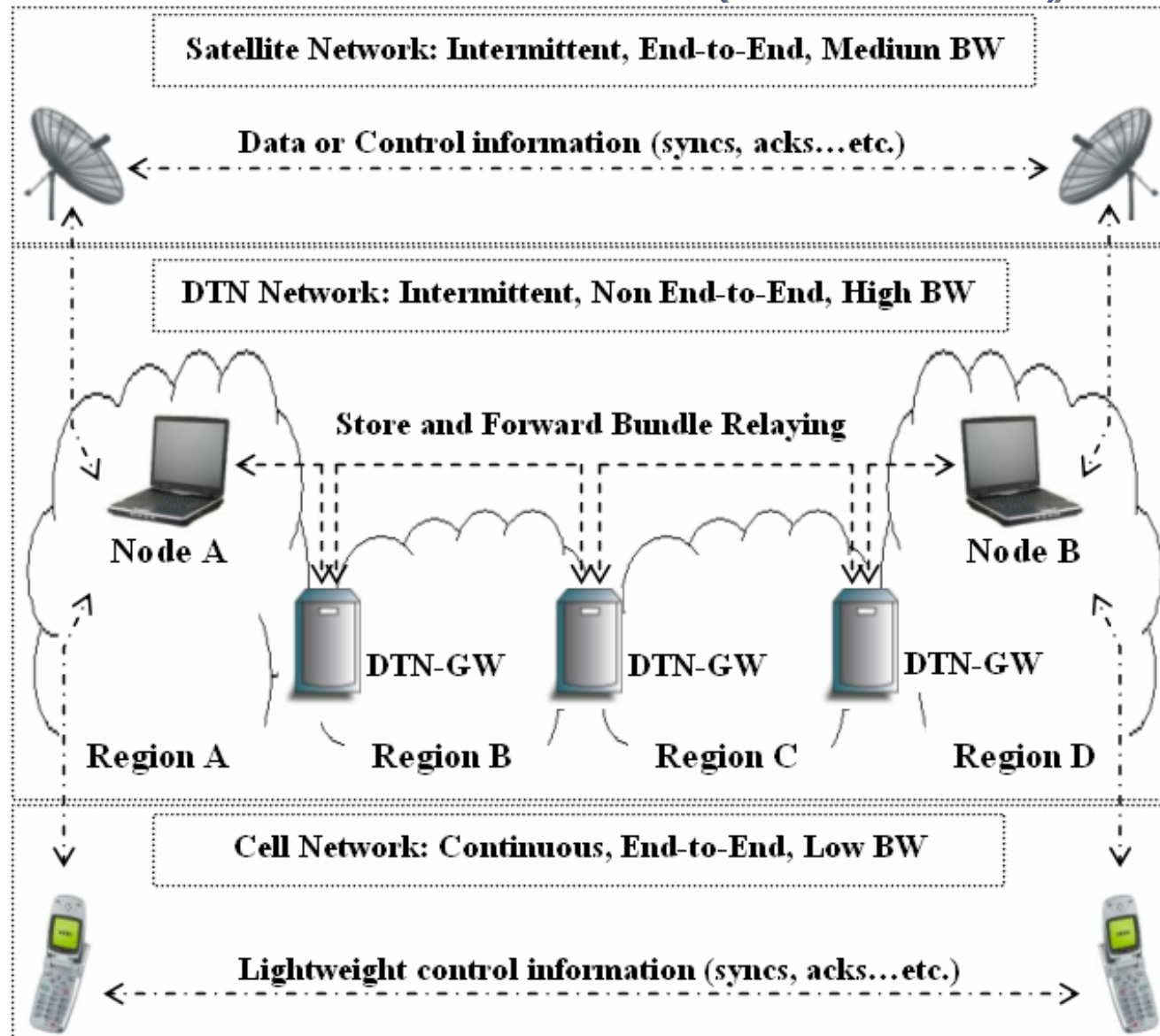


Store

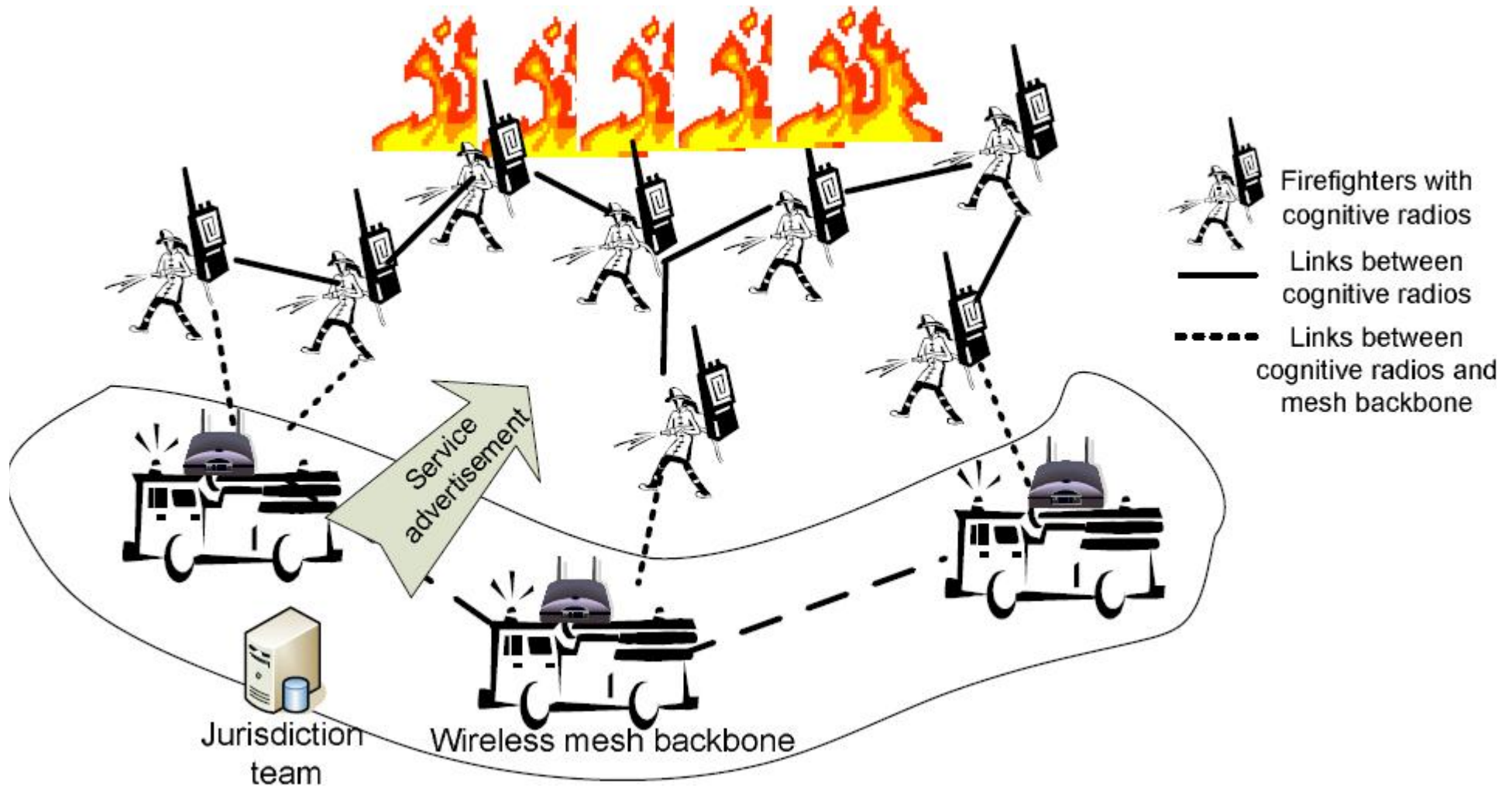
Two Ideas in One

- Improvement on *Epidemic Routing*
 - Mechanism to help nodes decide when to transmit
 - Best to only transmit when “uninfected” nodes are in range
 - Tradeoff between resource usage and incentive
 - Need feedback to tie broadcast with likelihood of success
- Addition of an *Incentive Mechanism*
 - Balance requirements: operators, customers & users
 - Should the system be fair (and is it)?
 - Can users be incentivized not to misbehave?

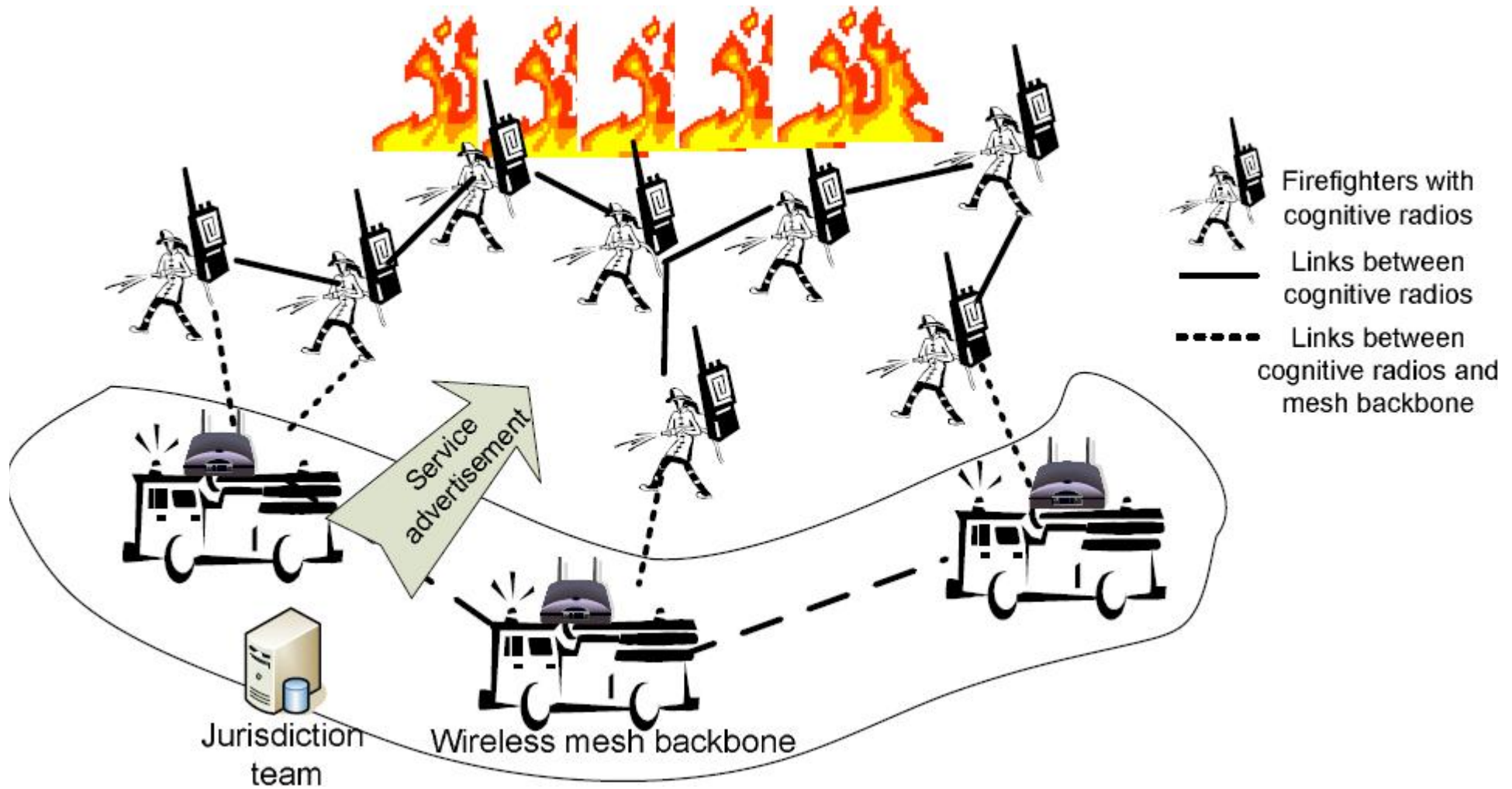
Parallel Networks (ParaNets)



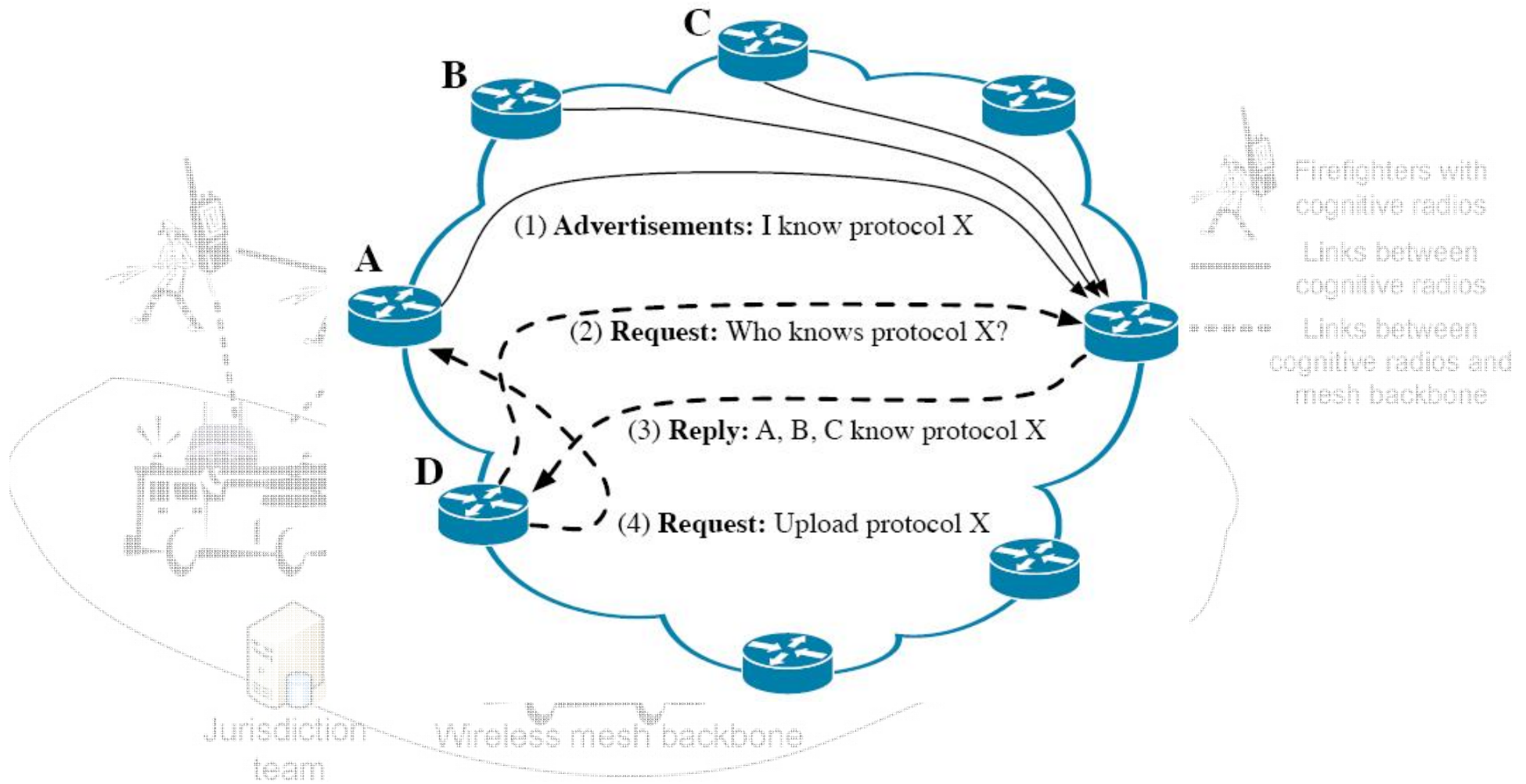
Disaster Recovery



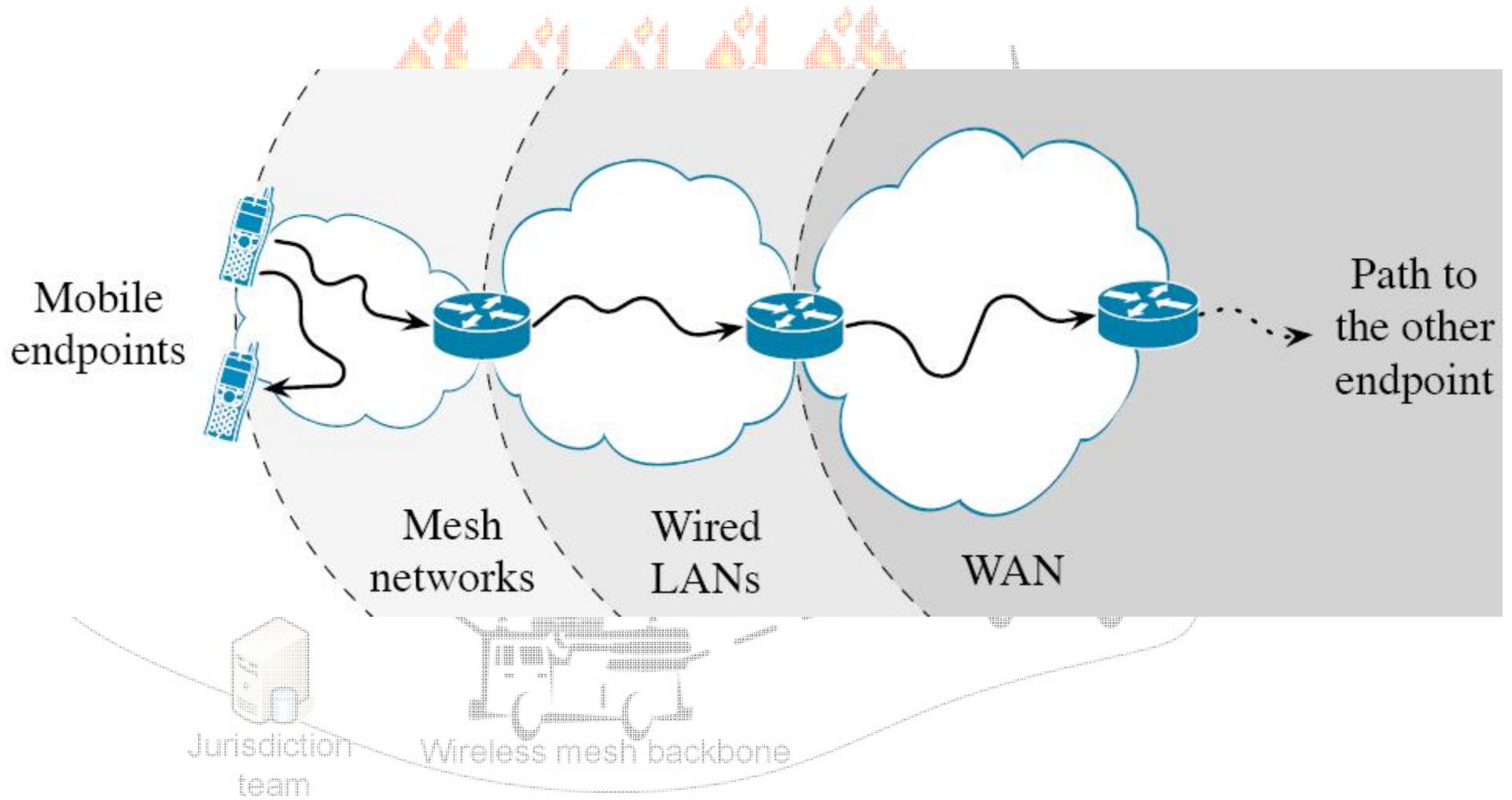
Disaster Recovery & NSF FIND



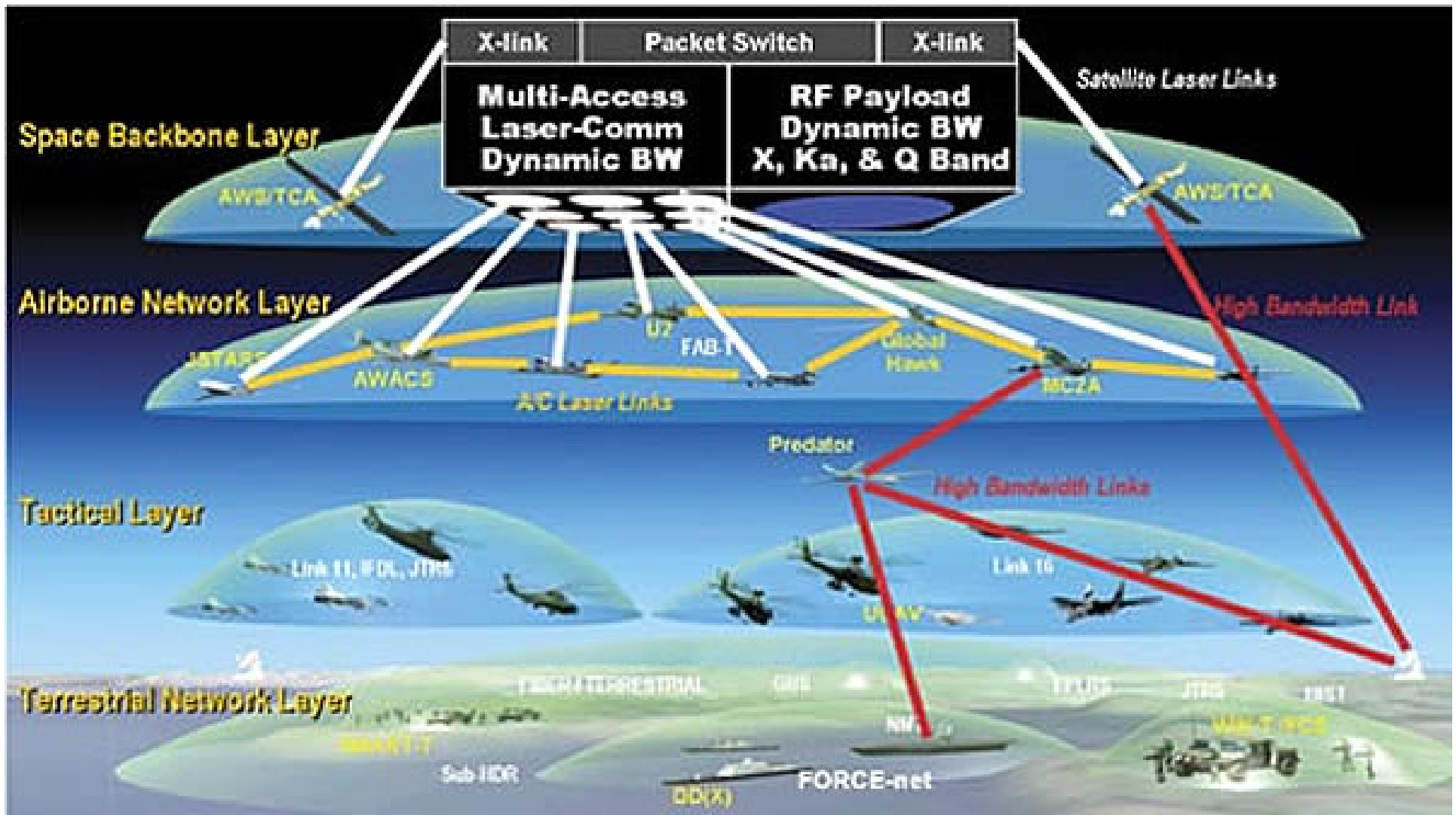
Disaster Recovery & NSF FIND



Disaster Recovery & NSF FIND



Transformational Communication (TSAT)



Some Interesting Ideas

- Multi-Hop Mesh Networks
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The Next Generation of Challenges

- Loss Rates (scintillation)
- Mobility
- Delay
- Storage
- Heterogeneous Network Paths
- Device Characteristics/Capabilities
- Topology
- Connectivity

Dangers!

There are enough environments, applications, parameters, and metrics to iterate forever.

It takes almost no effort (just grad student cycles) to endlessly simulate every new incremental variation.

There is an inflection point for “usefulness” in routing protocols, and most are no where close.

Key Points

- How well is the CHANTS model fairing?
- What are the next steps?
 - The next venue is...
 - Build the community...

By Way of Conclusion

- How well is the CHANTS model fairing?
- What are the next steps?
 - The next venue is...
 - Build the community...