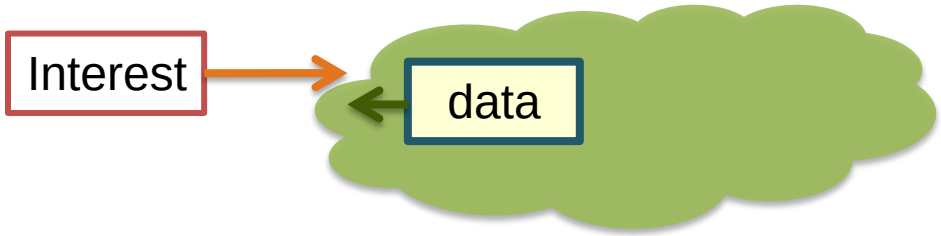
Information Centric Networking to Support Disaster Management

K. K. Ramakrishnan
WinLab, Rutgers University, NJ
(thanks to all the partners of the GreenICN EU-Japan project)

Content Centric Networks

- Use of Communications Networks has become largely Information-centric
  - Information of all types becoming electronic and network accessible
  - Access of information primarily by its name, instead of location
- Obtain "information" of interest by asking the network



  - CCNs separate the objective of retrieving data from the specifics of how to accomplish it
- Information Overload: Producers and Consumers face scale challenges
  - Large number of producers (publishers; data sources)
    - Tremendous number of information producers makes it difficult for a consumer to know where to find relevant information
  - Even larger number of consumers (subscribers, users querying/looking for content)
  - Challenge: "whom and what to ask" & "whom and what to tell"

Disaster Management

- Communication is a key component in managing Disasters
  - **Timeliness** is key to delivering critical information
  - **Coverage** of necessary and appropriate information related to the disaster is also important
    - E.g., May be difficult to depend on information aggregators and commonly accessed search engines
- Critical to efficiently distribute disaster notification and rescue information
  - Safety confirmation from refugees to their relatives and friends
  - Delivering emergency messages from local governments to refugees
  - Sharing information between local governments and refugees
- Energy and communication resources are at a premium after a disaster
  - Base stations, end-devices running out of power
    - Need to work on prioritization and reliability of communication
- Networks may be fragmented
  - Establish communication between communities with only intermittent connectivity.
    - Certain routes not available, servers unreachable, presence of mules, Delay tolerance

Disaster Scenarios

- Disasters cause:
  - Link failures
  - Base-station failures
  - Increase in traffic demand (people want to use the network more)
- In the case of the East Japan Earthquake (March 11, 2011)
  - Up to 64% of base stations were reported out of order
  - Traffic demand increased 9-fold
  - 90% of calls had to be dropped – network couldn't handle demand

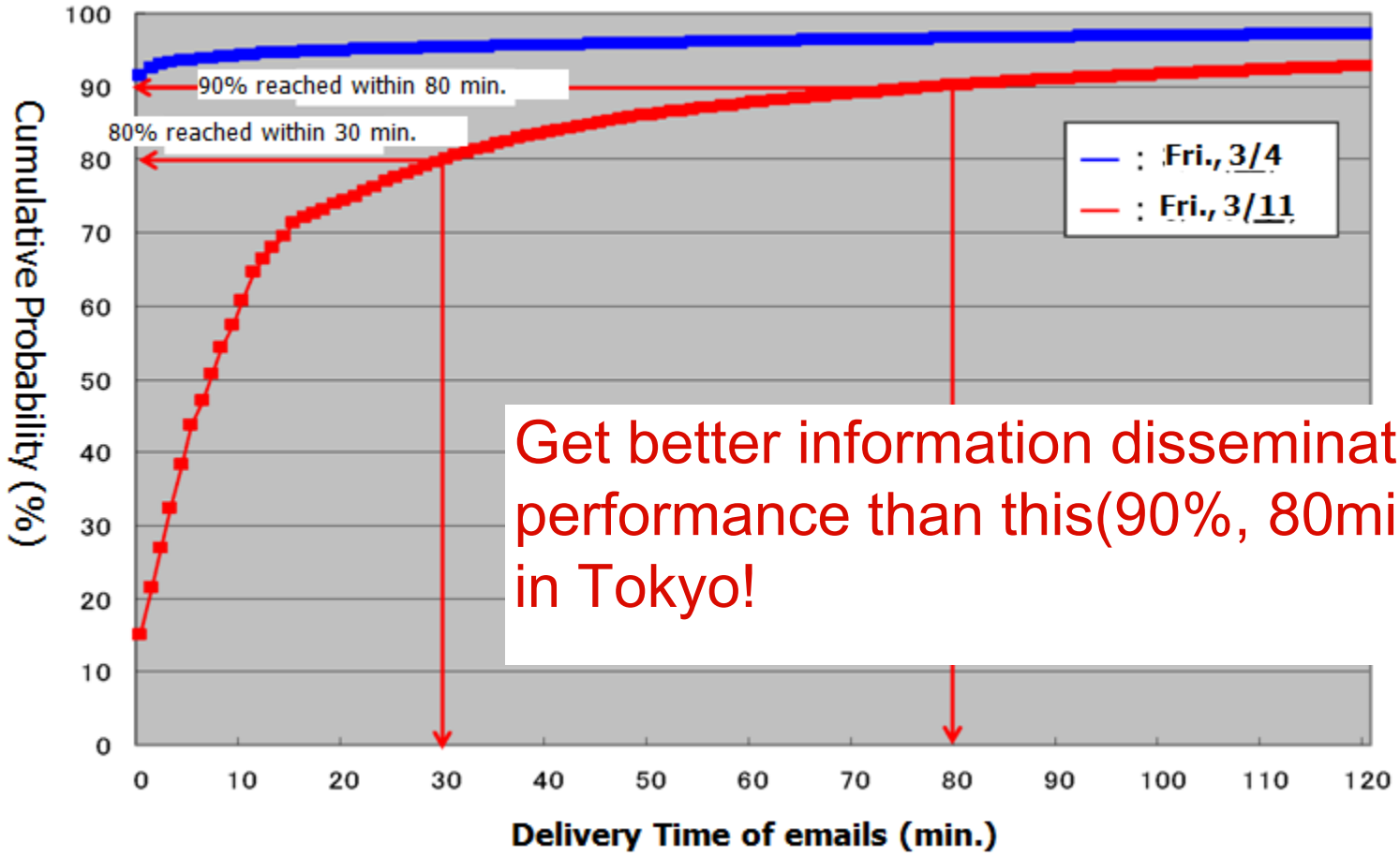
Ad Hoc Communication is necessary to improve *Communication Resilience* instead of only Network Resilience

Communication: Needs and Roles

- Communication network used to:
  - Seek for help
  - Distribute important information
  - Manage rescue teams
  - Get in touch with friends and family
- Authorities need to communicate critical information with dynamically formed teams
  - Compsition of team members unknown, except the ‘name’ of the team
  - Need for both querying for information and publicizing information
- Need to be able to identify *both* senders and receivers by name
  - Recipient hierarchies enable manage and control of information disseminated to manage situation
    - Sub-teams within a particular authority (e.g., police) only need to know
    - Geographical limits on relevance of information

Delivery Latency of Emails

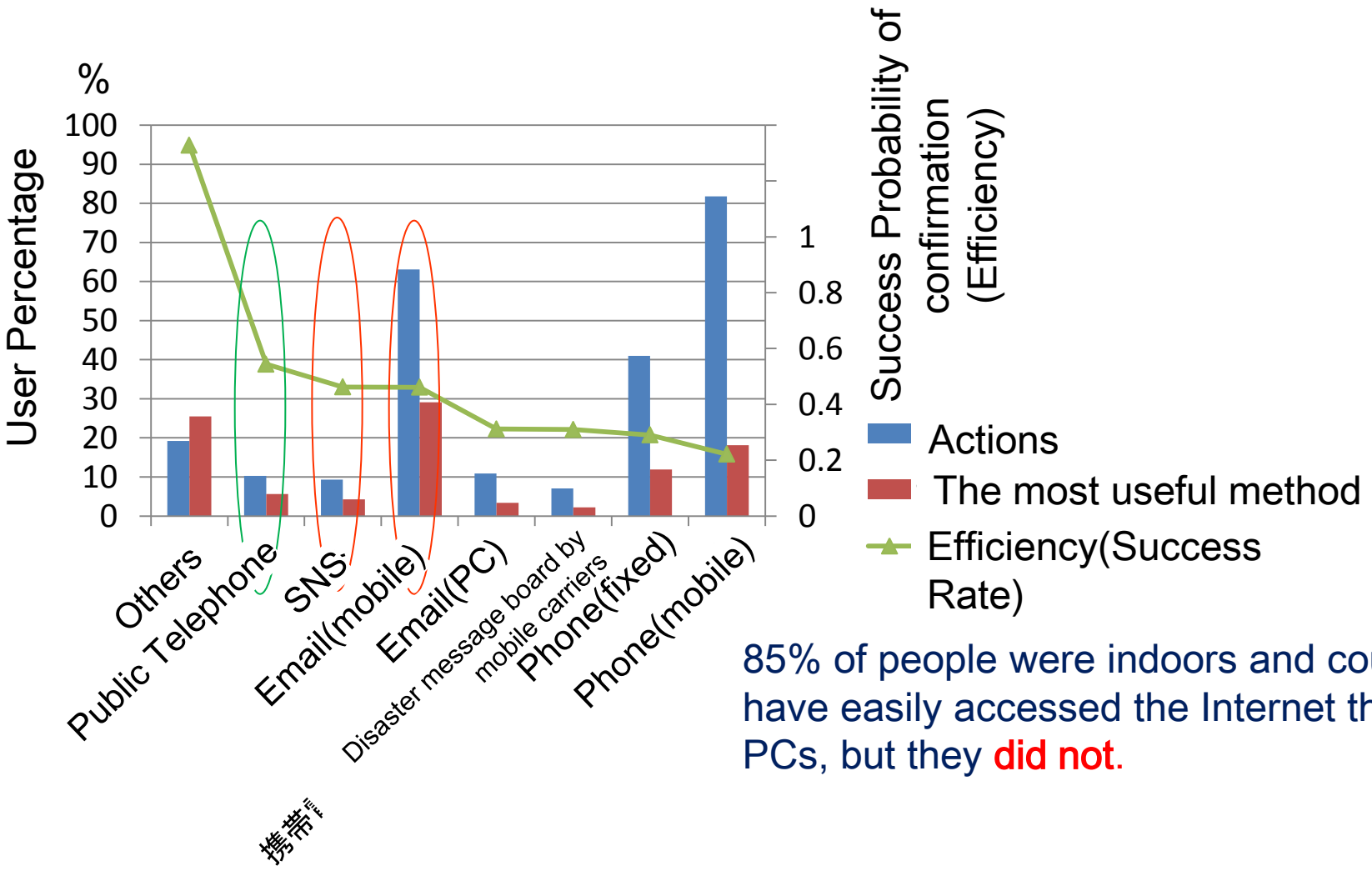
This figure shows the delivery times of emails exchanged between users in Kanto-Koshinetsu region from 14:46 to midnight on Mar. 4 and Mar. 11



Get better information dissemination performance than this(90%, 80min) in Tokyo!

Ref: http://www.soumu.go.jp/main_content/000117676.pdf

Confirmation Methods of Individual's Safety within 30 min after the shock

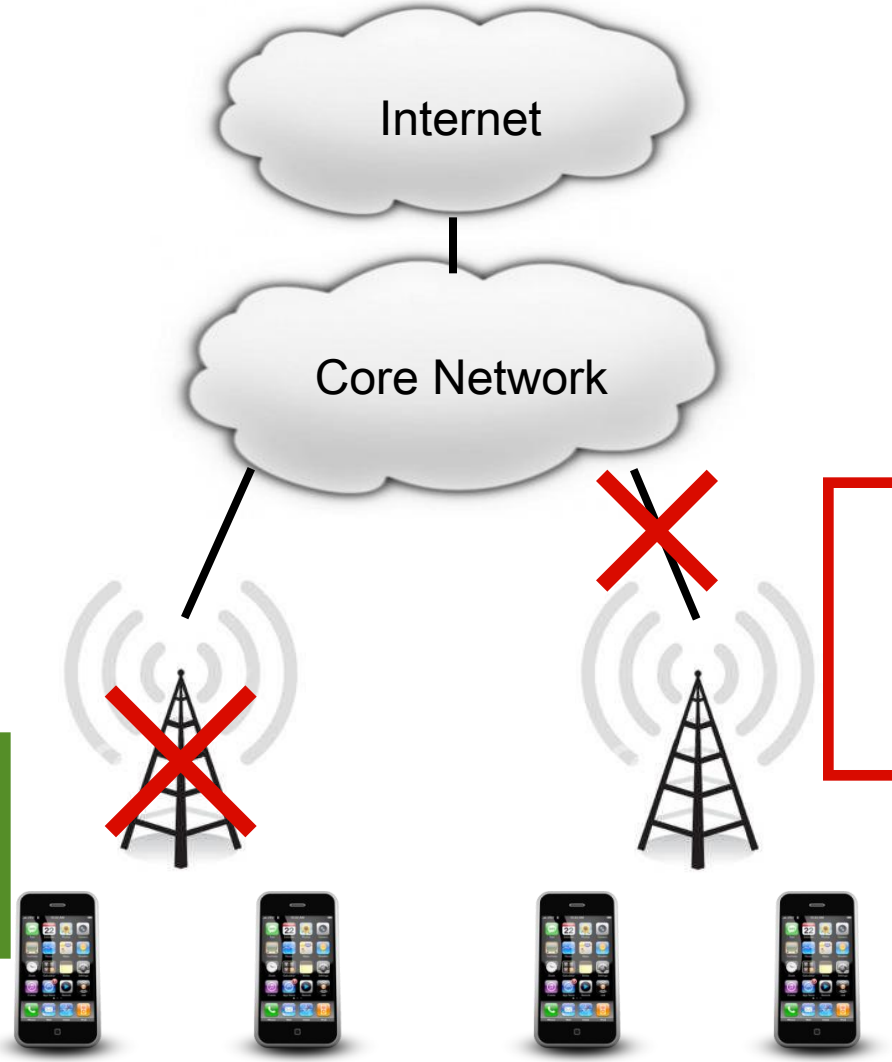


85% of people were indoors and could have easily accessed the Internet through PCs, but they **did not**.

Ref: The Asahi Shimbun, Jun.4,2011

Cellular Network after a Disaster

The Great Japan East Earthquake



Blackout
85%

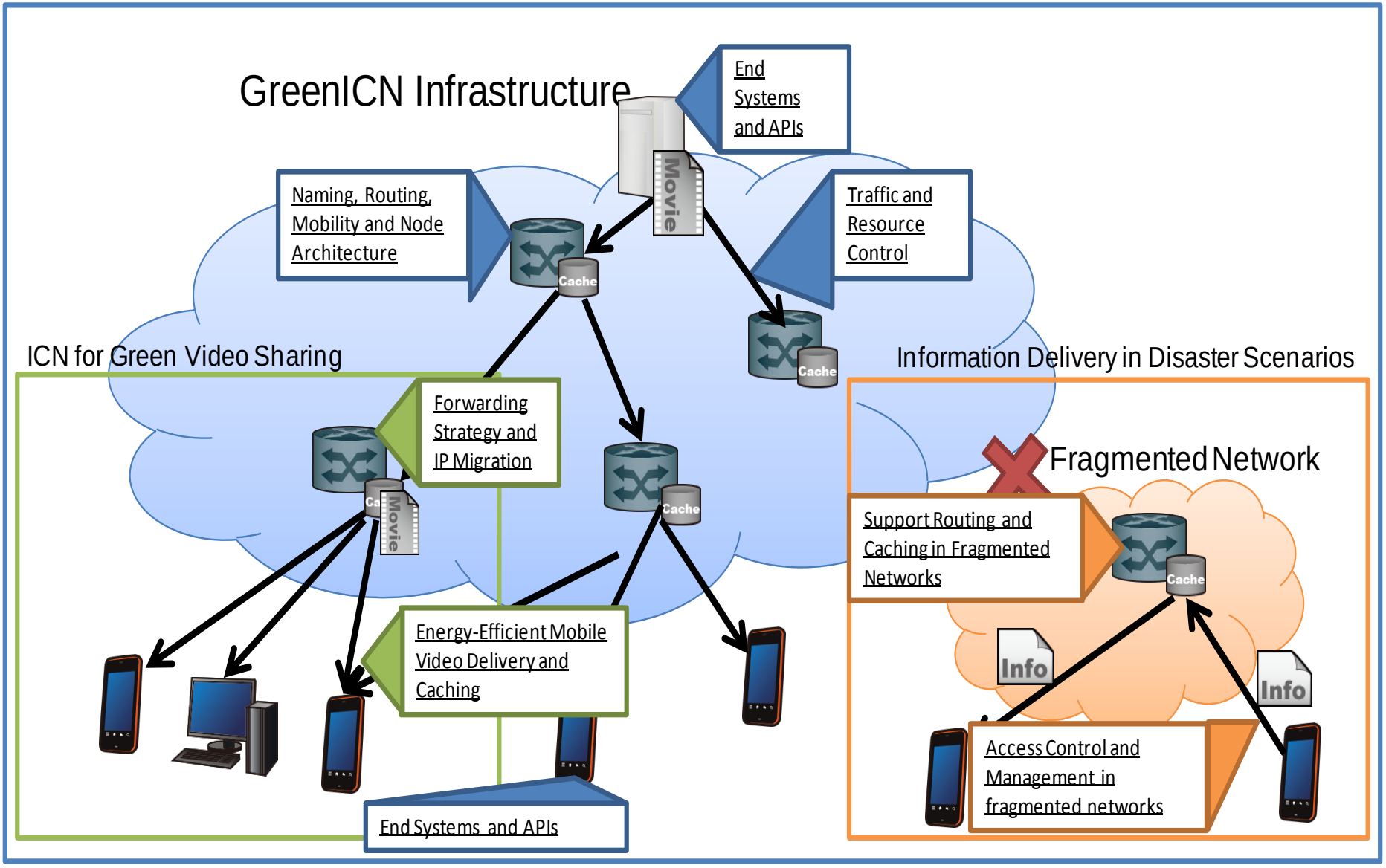
BS broken
6%

Backhaul
Failures
9%

Cellular Network during Disaster Situations

- Cellular-based ICN networks desirable
  - People use the communication means they are used to during normal conditions
  - Battery-operated base stations (BSs) are the most critical from energy perspective to provide connectivity during the days after a large-scale disaster
- Providing connectivity between fragmented networks due to failures and blackouts is key feature
  - We evaluate various solutions in fragmented networks
- Focus on “communication resiliency” in addition to traditional notions of “network resiliency”
- Security concerns need to be handled: authorities are separated from other citizens by fragmented networks

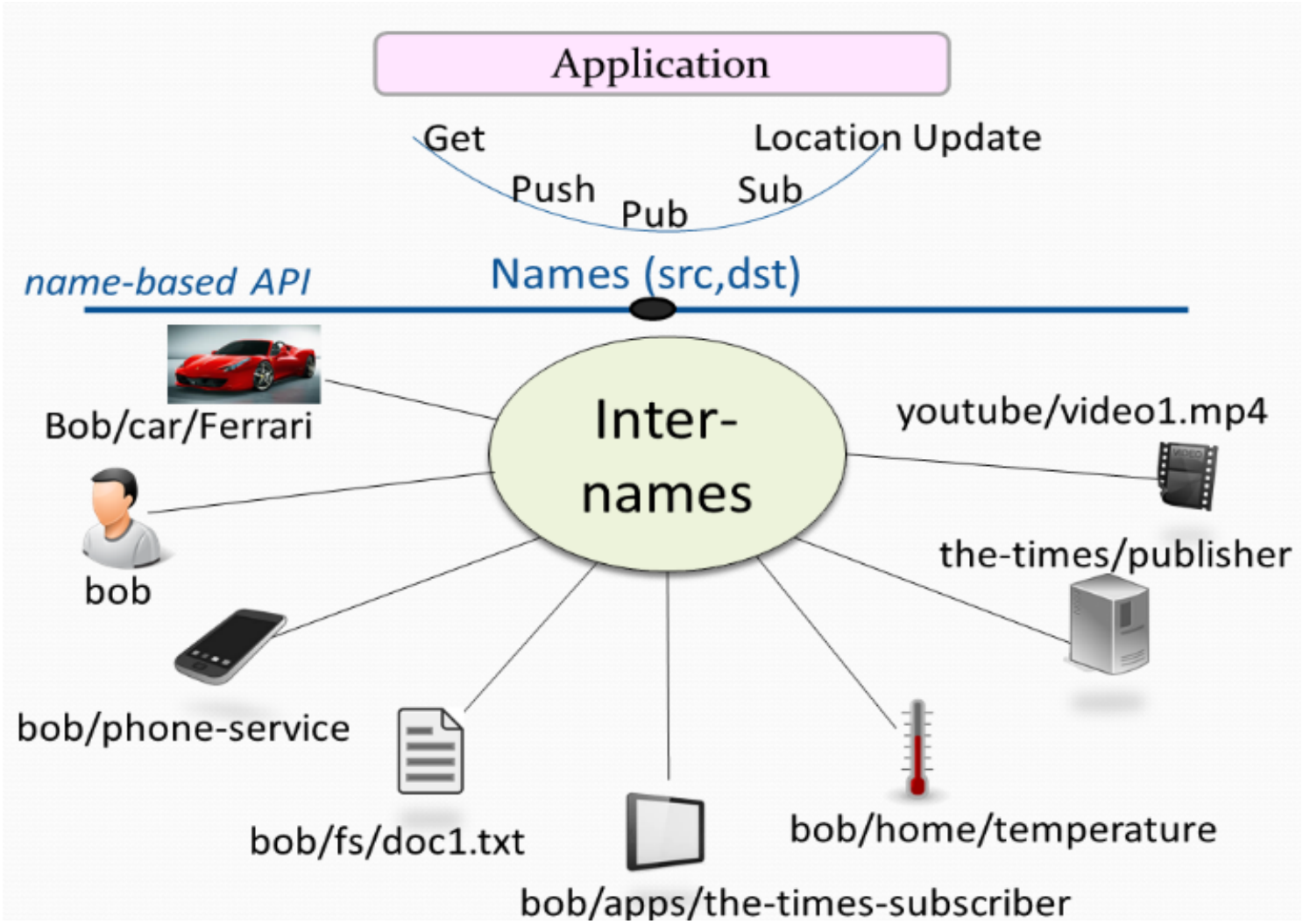
GreenICN Architecture



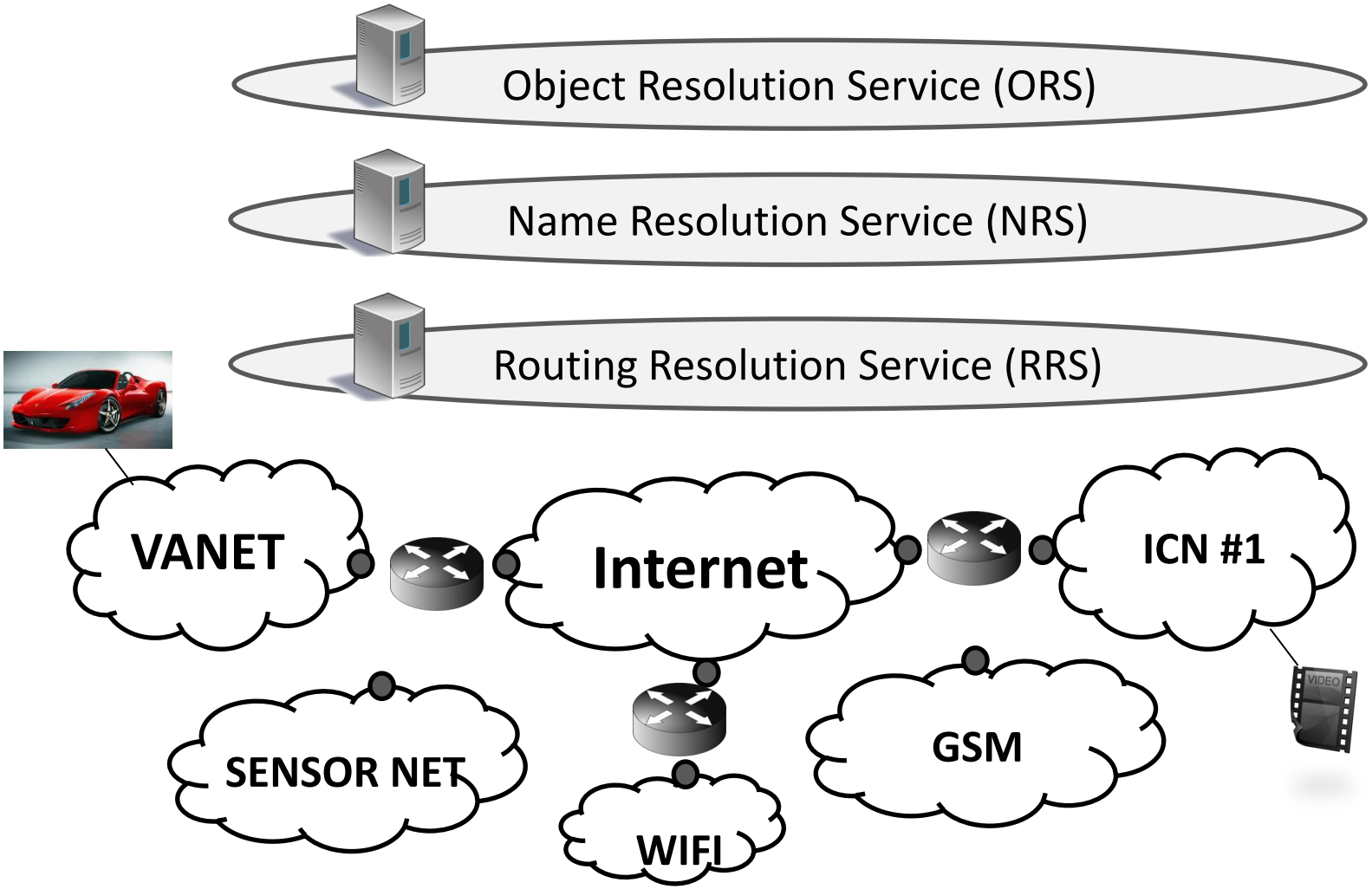
A Content Centric Framework for Disaster Management

- **Internames**: A name-to-name architecture
- Names identify all entities involved in communication:
  - content, users, devices, logical as well as physical entities and services
- Names are not statically bound to their current location
  - entities can be mobile, and can be reached by any of a number of basic communication primitives
  - the communication path can be dynamically bound to any of a number of end-points (**both** source and destination), and the end-points themselves could change as needed (unlike a host->name approach)
  - communication can span networks with different technologies and allow for disconnected operation
- Enhance communication resilience in fragmented networks
  - Naming scheme accounts for priority
  - Safety confirmation delivery mechanism
    - Enhanced Content Oriented Pub/sub (COPSS) for fragmented networks: disruption and delay tolerance
    - w/o the need for central mobility management, Mules are seen as logical links

Internames: A name-to-Name Architecture



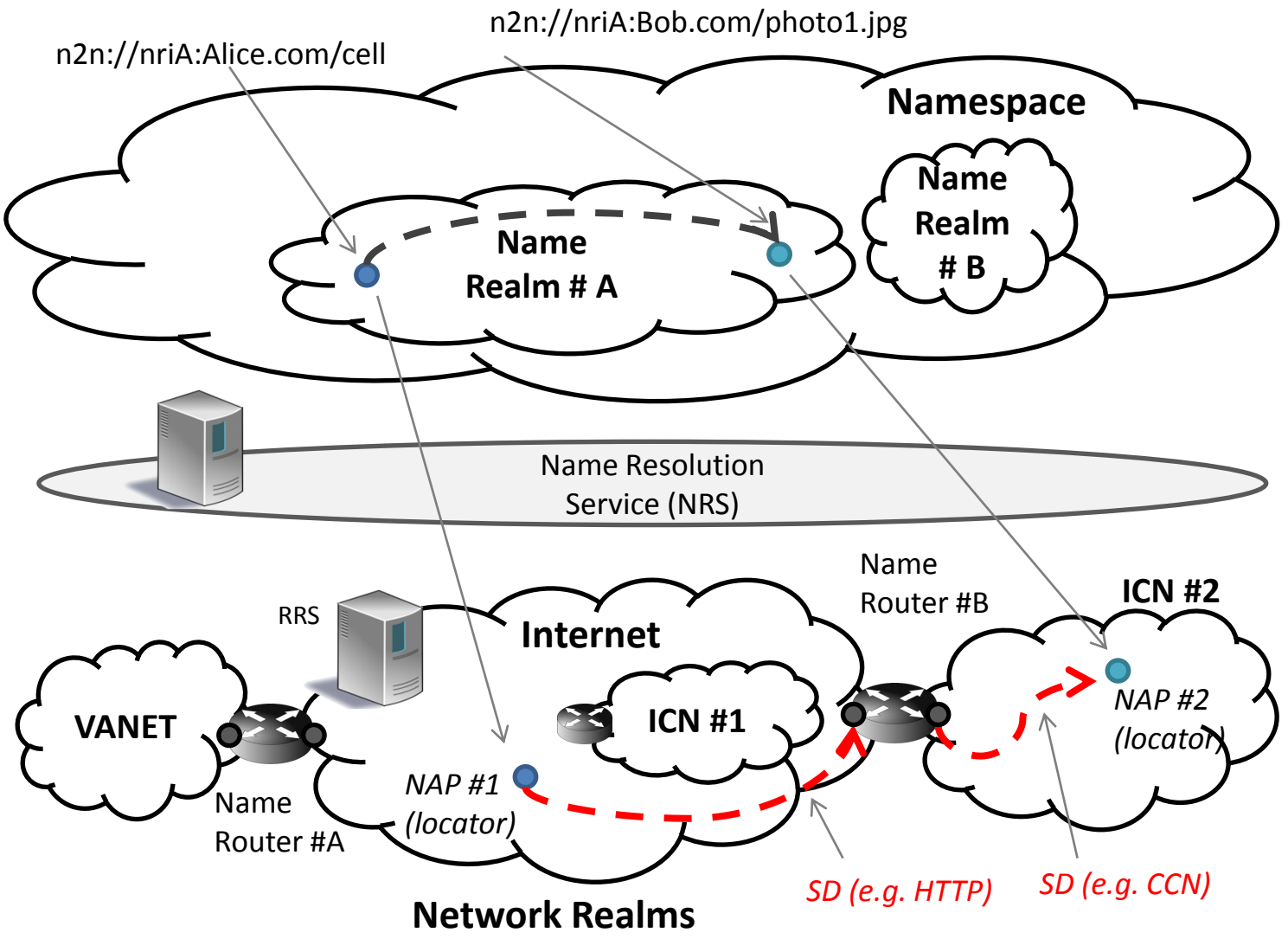
Architecture



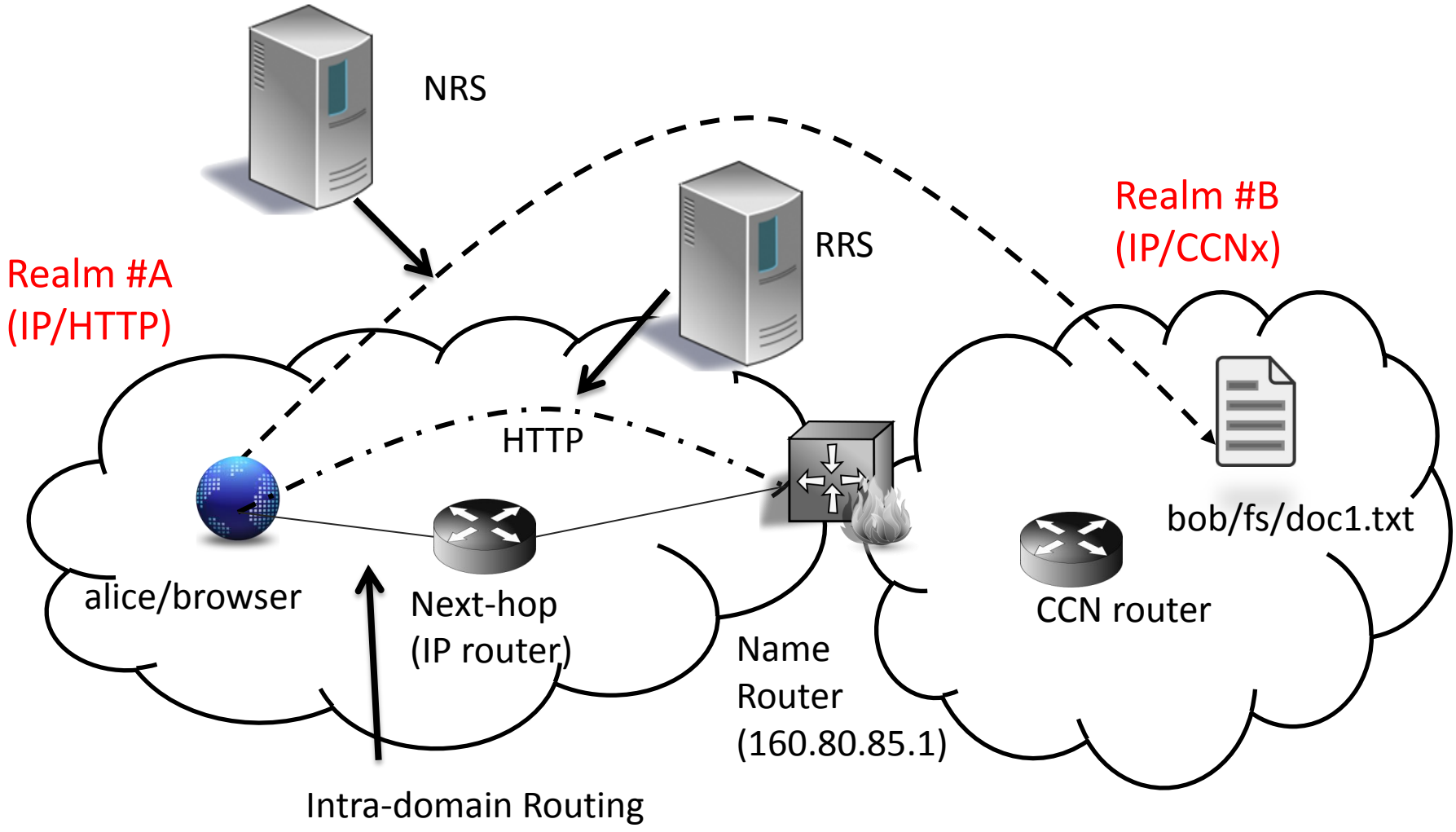
Internames: Name Resolution Service

- Key role played by the Name Resolution Service (NRS)
  - co-existence of multiple network “realms”, including current IP and non-IP networks, glued together by an over-arching name-to-name communication primitive
  - resolution can lead to different results as a function of policies
    - e.g., in disaster conditions names are resolved to different locations w.r.t. normal conditions, transparently to users
  - dynamic mapping to assure efficient mobility and resource management
  - complexity to be evaluated taking into account cloud computing and cloud networking functionality that would have been hardly predictable only few years ago (and Google)

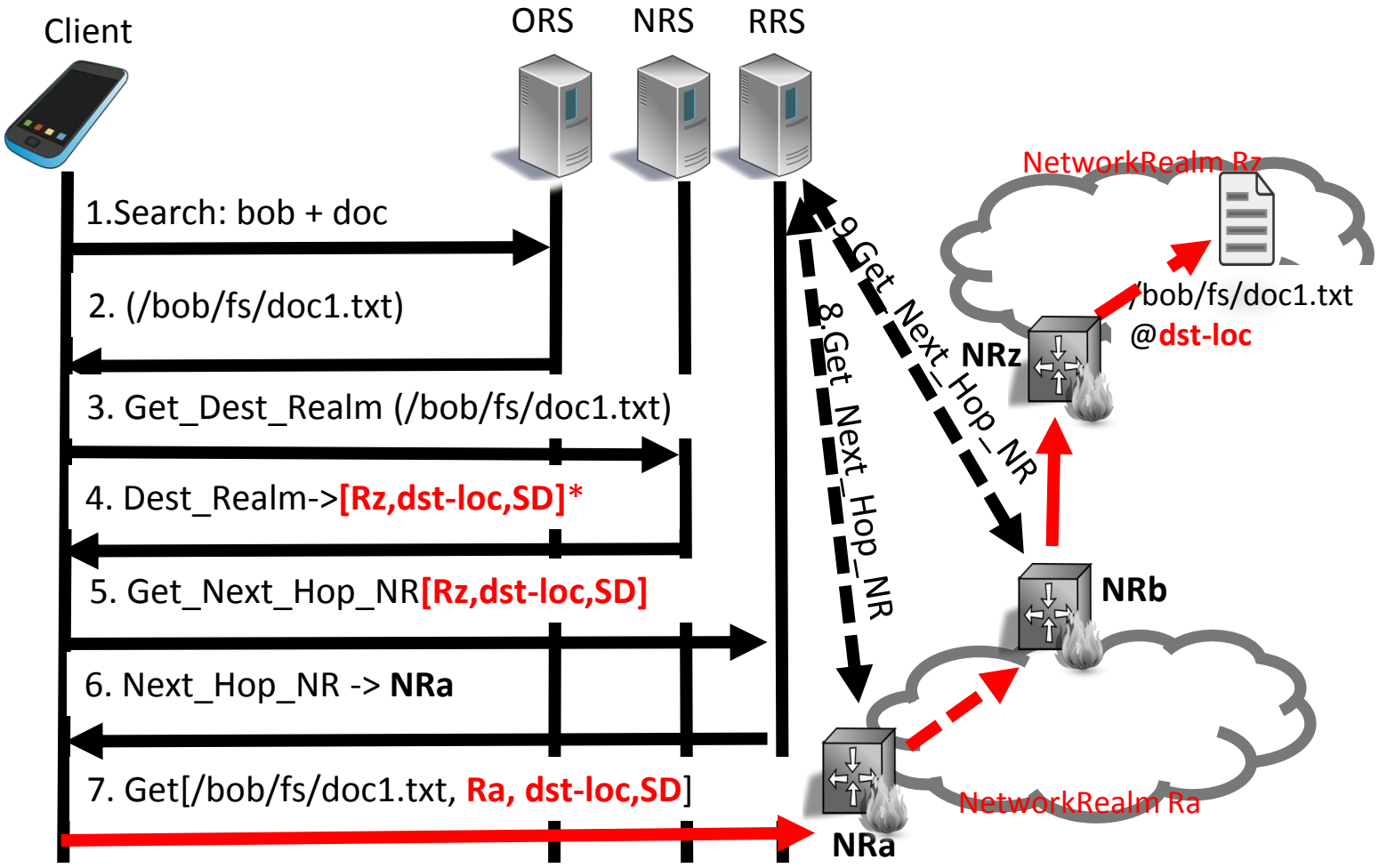
Architecture Components



Routing Example

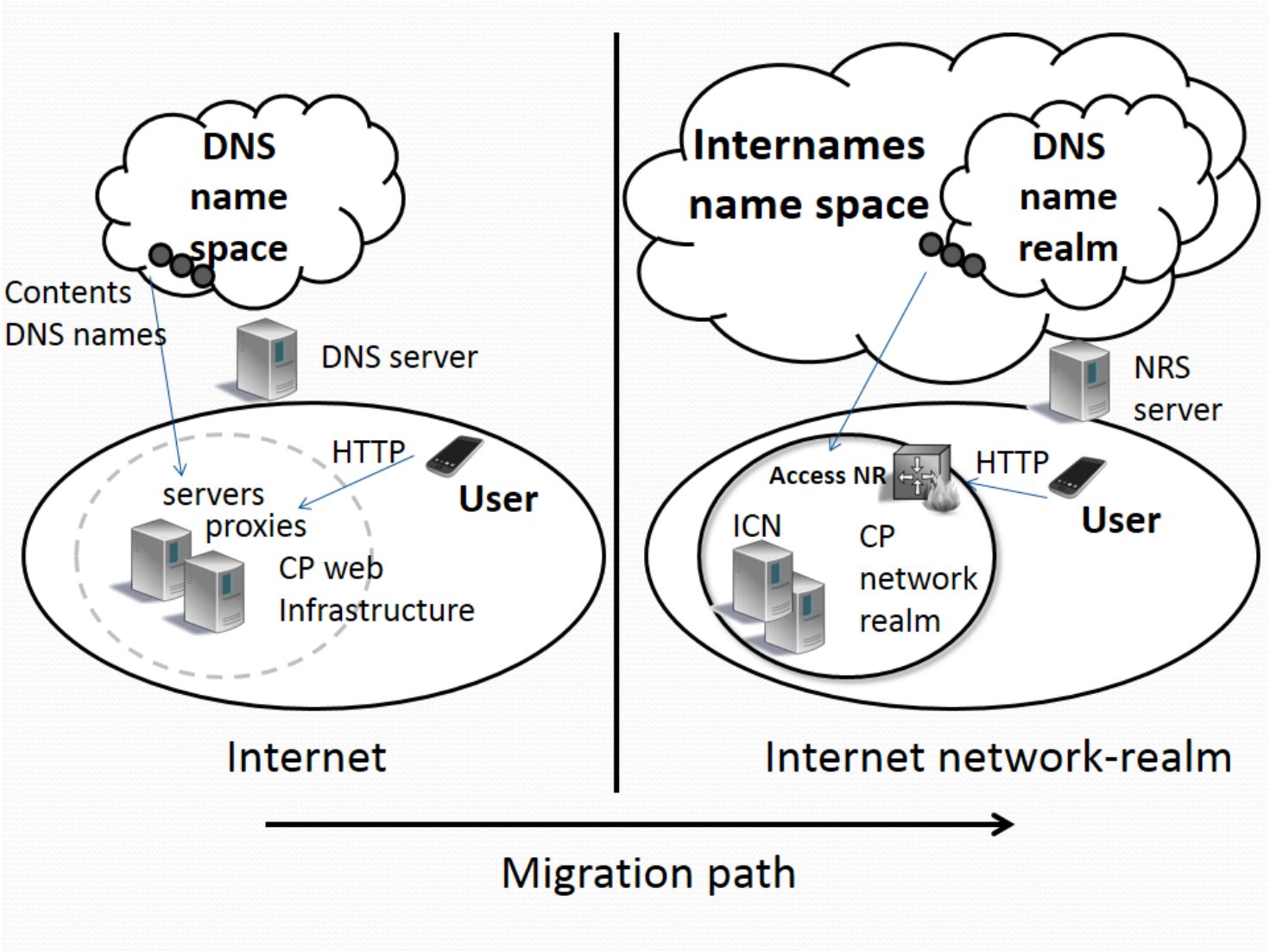


Simple Message flow



*: If NRS returns multiple Name Realms, client will have to choose

Migration


DNS
name
space
Contents
DNS names
DNS server
HTTP
User
servers
proxies
CP web
Infrastructure
Internet
Internames
name space
DNS
name
realm
NRS
server
Access NR
HTTP
User
ICN
CP
network
realm
Internet network-realm
Migration path

Advantages of Internames

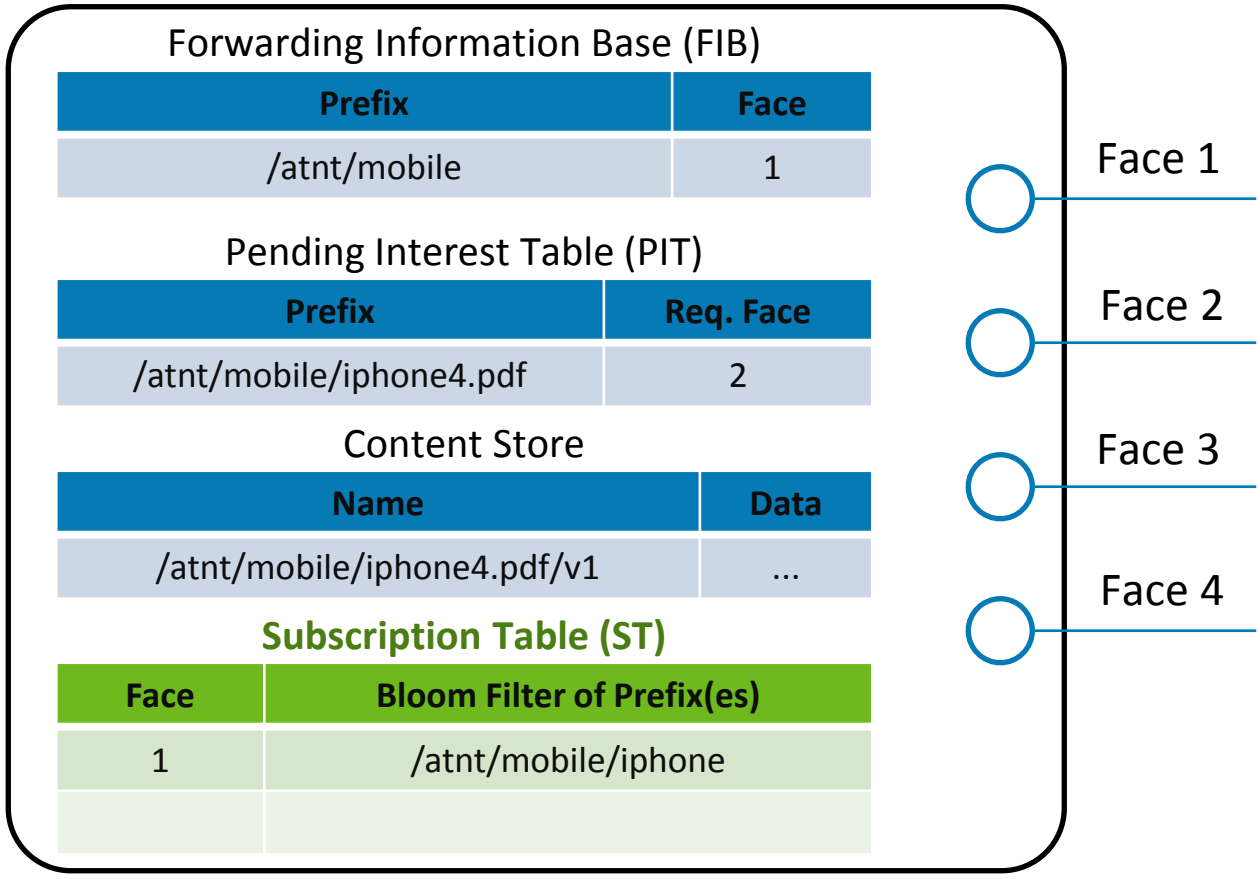
- End-Result
  - Unified framework and universal inter-operability, simplification of overall architecture
  - **Avoid disadvantages of some existing ICN frameworks**:
    - Routing scalability: high number of prefixes and update frequency
    - Security: e.g. users allowed to update the routing plane to make their content reachable
    - Stateful forwarding, by populating PIT entries
    - (D)DoS due to caching of fake content. Check of validity before caching is thus required (security engine in the router…costly)
    - Lack of smooth migration paths from current IP-centric networks
    - Cumbersome support for push services

Content Oriented Pub/Sub System (COPSS)

- Pub/sub is a desirable feature for information dissemination
  - Enables time/space-decoupled communications, especially in disruption-prone and fragmented networks
  - From the point of view of a publisher:
    - Time of publication independent of when the data is queried
  - From the point of view of a subscriber:
    - Have CCN take care of a query without having to be aware of when someone else publishes a piece of content
- COPSS approach
  - Built on top of NDN
  - CCN-oriented multicast capability
  - Efficiency and scalability
- We've built a disaster information dissemination framework on top of COPSS

COPSS Introduces Pub/Sub in CCN

- NDN (query/response): FIB, PIT, Content Store [CoNext 2009]
- COPSS (pub/sub): ST [ANCS 2011]



Name-based Routing and Forwarding in fragmented networks

- In disaster scenarios:
  - End-end connectivity is not guaranteed
  - Network resource (include storage) is limited
- Routing and caching schemes for information dissemination
  - Consider power consumption when replicating messages
    - Avoid message flooding
- How to deliver message between fragmented networks?
  - Mobile device is not always connected to network
- Support for Publish/Subscribe in disaster situations:
  - Utilize data mules to deliver messages

- Separate the Logical interface (‘Face’) from the Physical interface

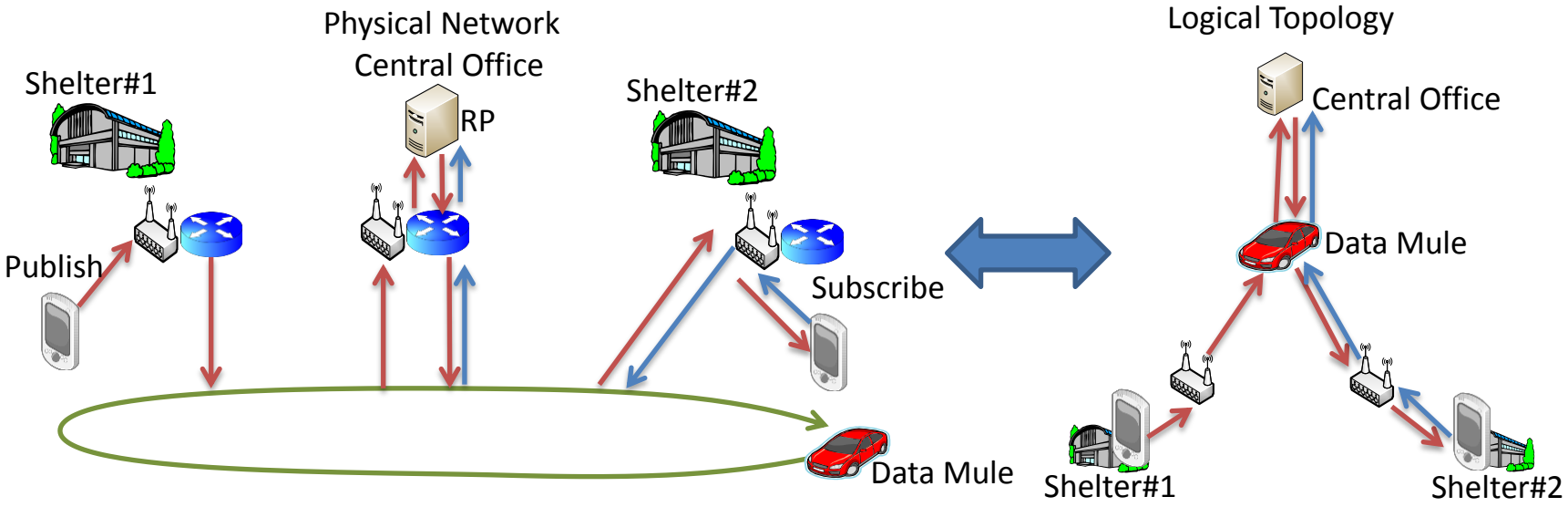
- Queue message on the ‘logical interface’
  - Buffer messages until the physical interface establishes an association with an appropriate ‘next hop’

Desirable Characteristics for CCN in Fragmented Networks

- Enable fragmented communities to exchange information
  - Utilize mules to implement content-centric, delay-tolerant communication system
- Deliver important messages with lower delay and better reliability
- Prioritize messages
  - Consider mule's destination, data importance and size
- Exploit the predictability of mule movements
  - Ambulances often go to hospitals, police to stations, etc
  - Data mules (drones, buses...) have fixed paths
- For query-response
  - Decouple interest and data path (avoid PIT and related rules such as time-outs)

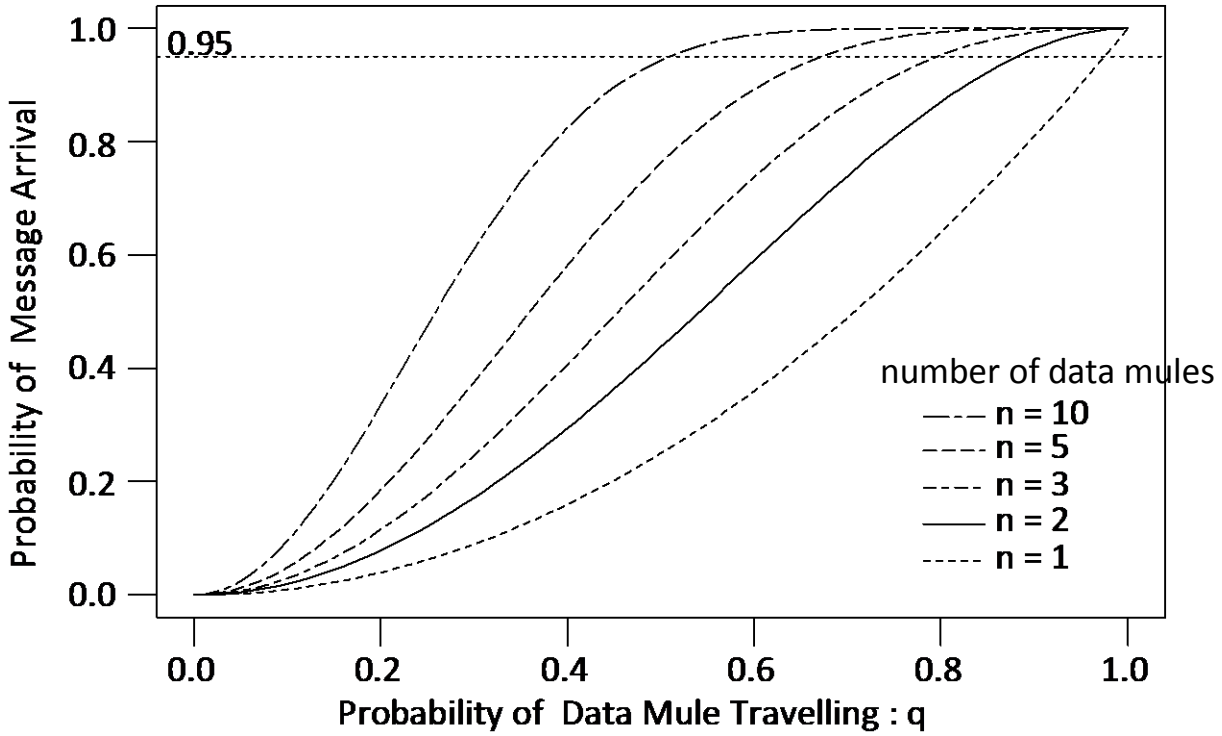
Name-based Routing with COPSS

- Consider the safety confirmation scenario
  - A user knows the name of person whose safety is being disseminated
- Links of logical topology constructed over a 'dynamic' physical network
- Extend COPPS
  - Avoid timeouts of the query-response type architecture
- Routing by FIB and subscription table
  - Data mule has a route to RP on FIB and subscription table



Effectiveness of Routing

- Analyze the message arrival probability from publisher to subscriber
  - Data mule does not always go on the same route
  - If there are 10 data mules, 95% messages arrive to subscribers even if a data mule follows the route with 50% probability.



Summary

- Communication is a critical component in managing disasters
  - For authorities
  - For people affected by the disaster
- A name-based communication interface can be a key to providing timely information with much needed convenience
  - Internames further enhances current information-centric network architectures with a name-name framework for sources and destinations
- Network fragmentation is likely
  - Communication Resilience is desired
  - Integrate ICN and DTN concepts
- We’re doing these as part of the GreenICN project - a EU-Japan joint, cooperative effort