Network Coding in ICNs
IRTF, Nov 2013

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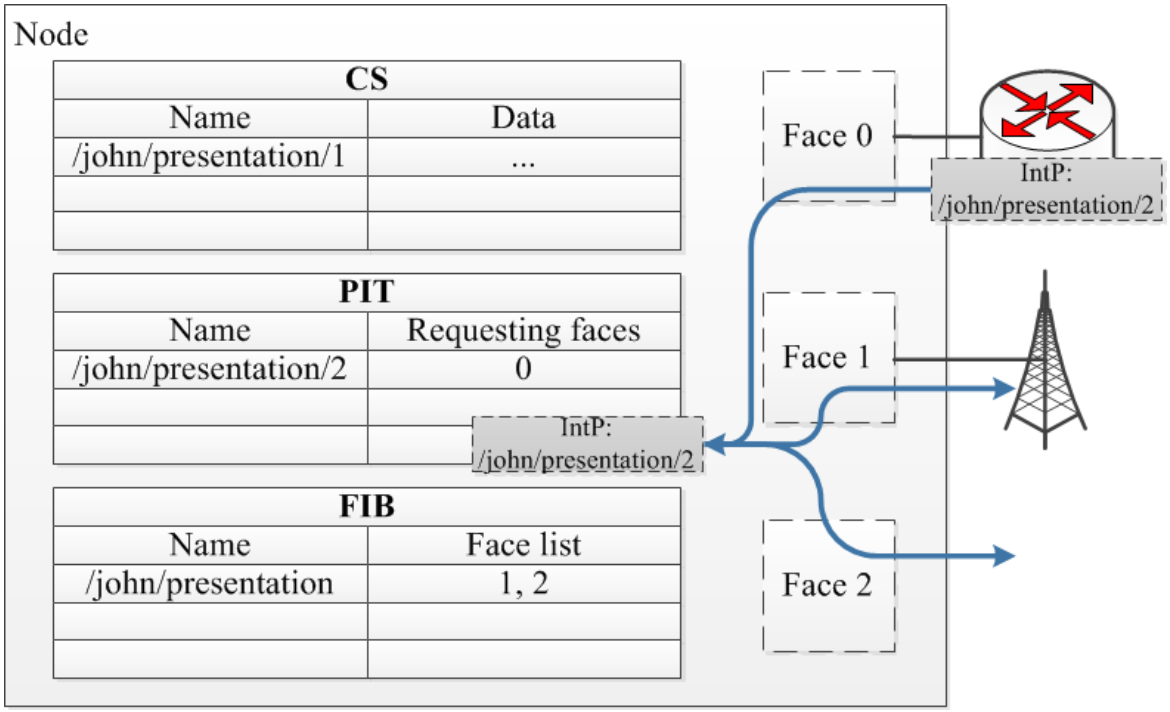
Named Content Networks (NCN)

Unique named segmented objects	• Object/segment is identified by names • e.g. /spiderman3/1, /spiderman3/2, …
In-network caching	• +Resistance to mobility • +Scalability
Pull-based transport	• Data consumer pulls data by expressing interests • + Good for consumer mobility
Name-based forwarding	• +Possibility of multipath/multisource retrievals • +Exploit wireless broadcast nature

Content-Centric Networks (CCN)

- Replace IP layer
- Interest forwarding: broadcast (flood) on an interface
- Data forwarding: breadcrumb routing

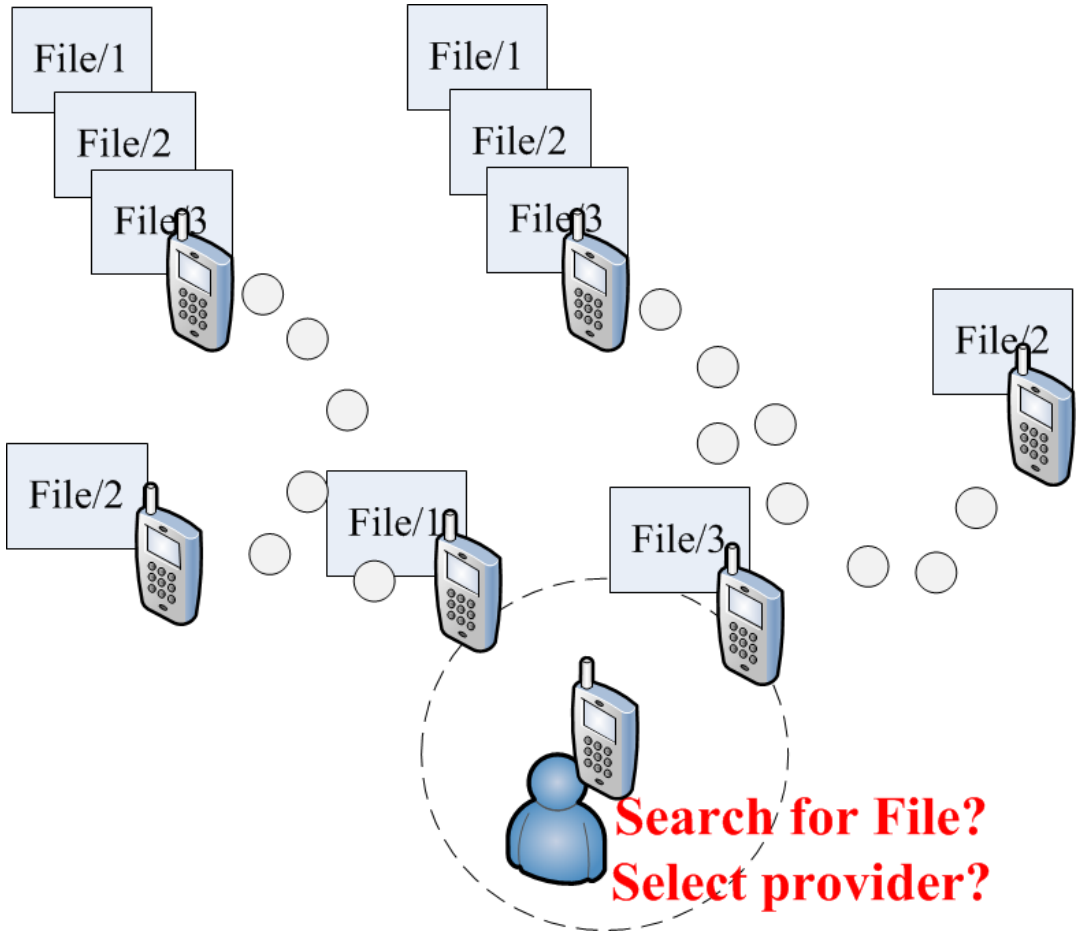


Named content retrieval in MANETs

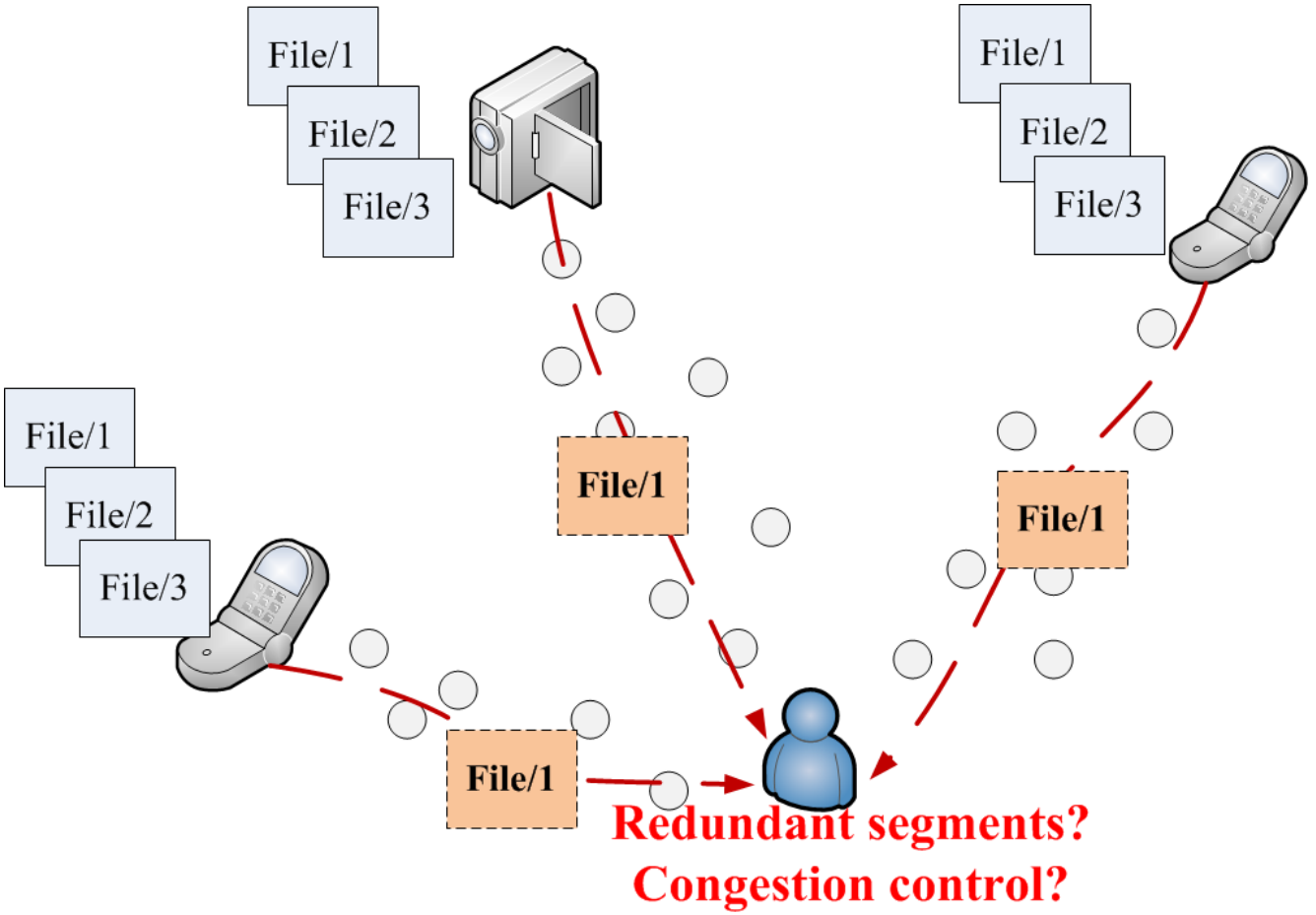
- Data discovery
- Interest propagation
- Data forwarding

- The tradeoff between
  - Robustness
  - Efficiency

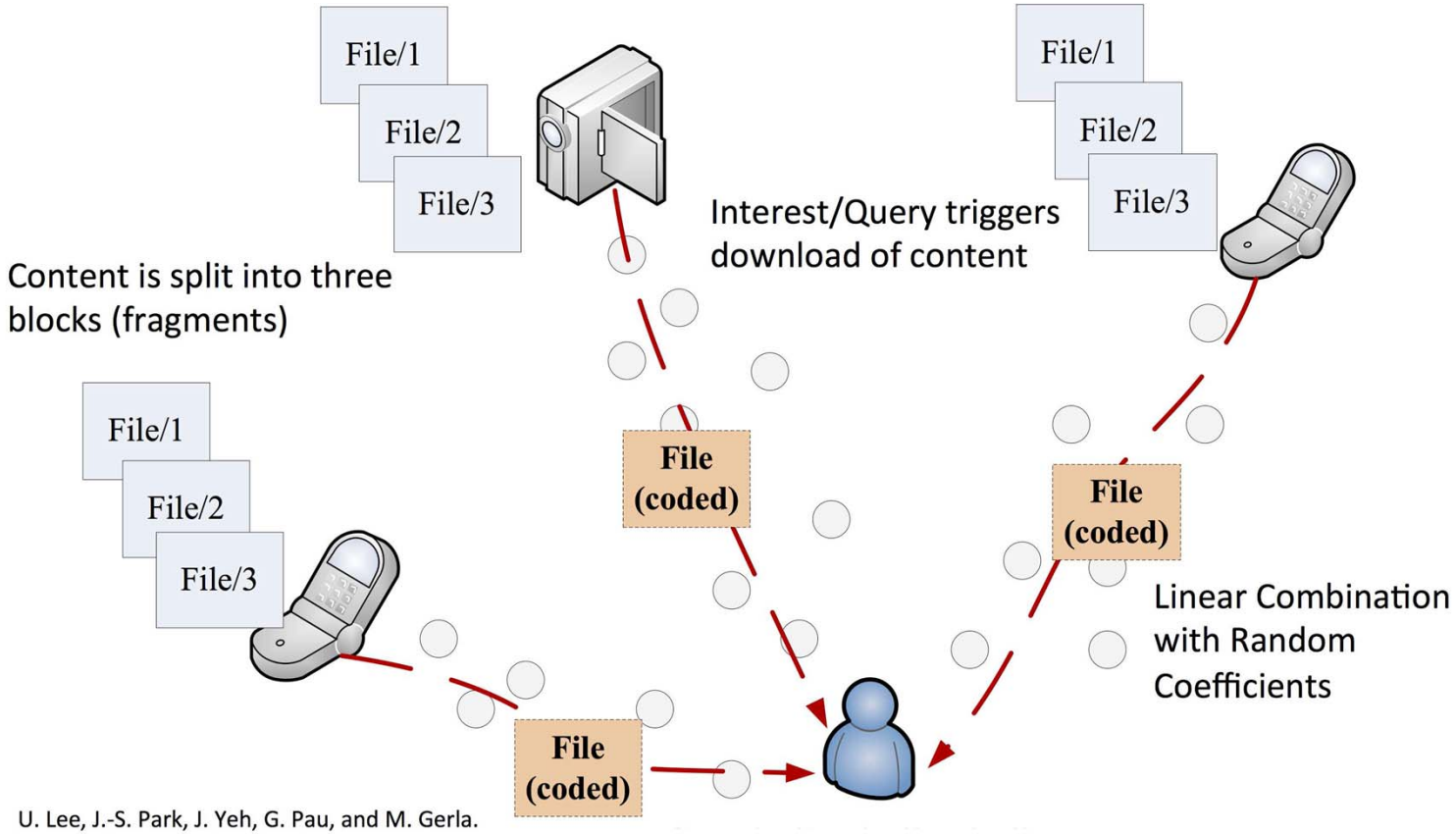
Data discovery and interest propagation



Multisource data retrieval



Data retrieval with Network Coding



U. Lee, J.-S. Park, J. Yeh, G. Pau, and M. Gerla. Code torrent: content distribution using network coding in VANET. In *Proceedings of* MobiShare'06.

Three Coding options

- **Unrestricted coding**
  - All nodes encode available blocks.
  - Highest block diversity but vulnerable to pollution attack.
- **Source only coding**
  - Only the source of the file (publisher) may generate new encoded blocks. Intermediate nodes only cache and forward encoded blocks.
  - Low block diversity => weak robustness to channel losses
- **Cache coding**
  - Caches that have reconstructed the full files can (like the source) encode.
  - Caches (like source) sign the newly encoded blocks

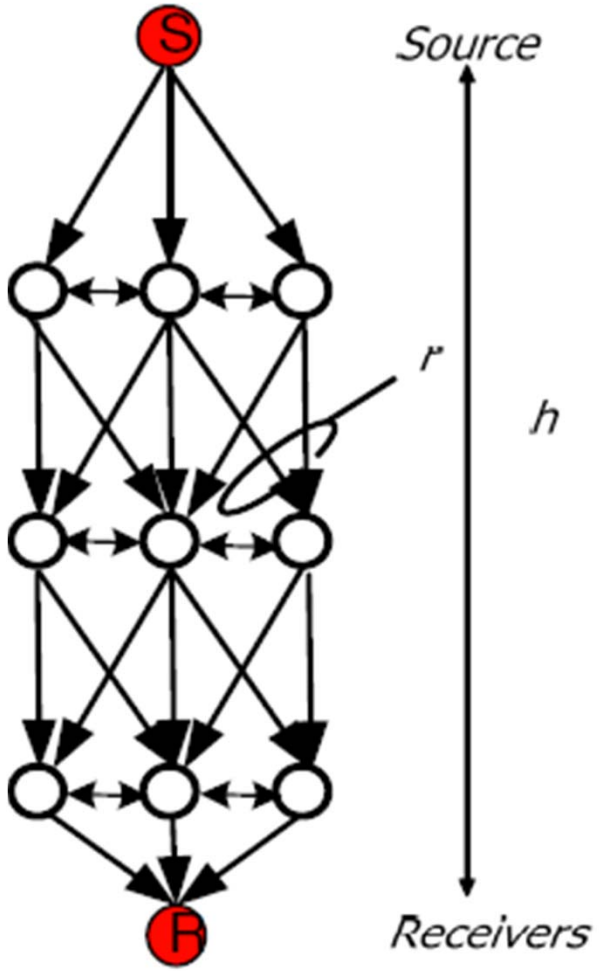
Why Cache coding

- Increases code diversity
- Protected from pollution
  - Each cache node signs (no repudiation)
  - Easier than homomorphic signatures..
- Performance approaches “unrestricted coding” bound for popular files (with several caches)

Simulation Experiments

- Qualnet 6.1 simulator
- Multiple publishers disseminate files using broadcast.
- The network is intermittent due to interference, packet loss, and, in the dynamic case, mobility.
- Receiver can download from multiple caches in parallel.
  - Due to the broadcast mode, there are no retransmissions.
  - Redundancy is provided by multiple paths.
  - After timeout, the decoder discards file that cannot be decoded.

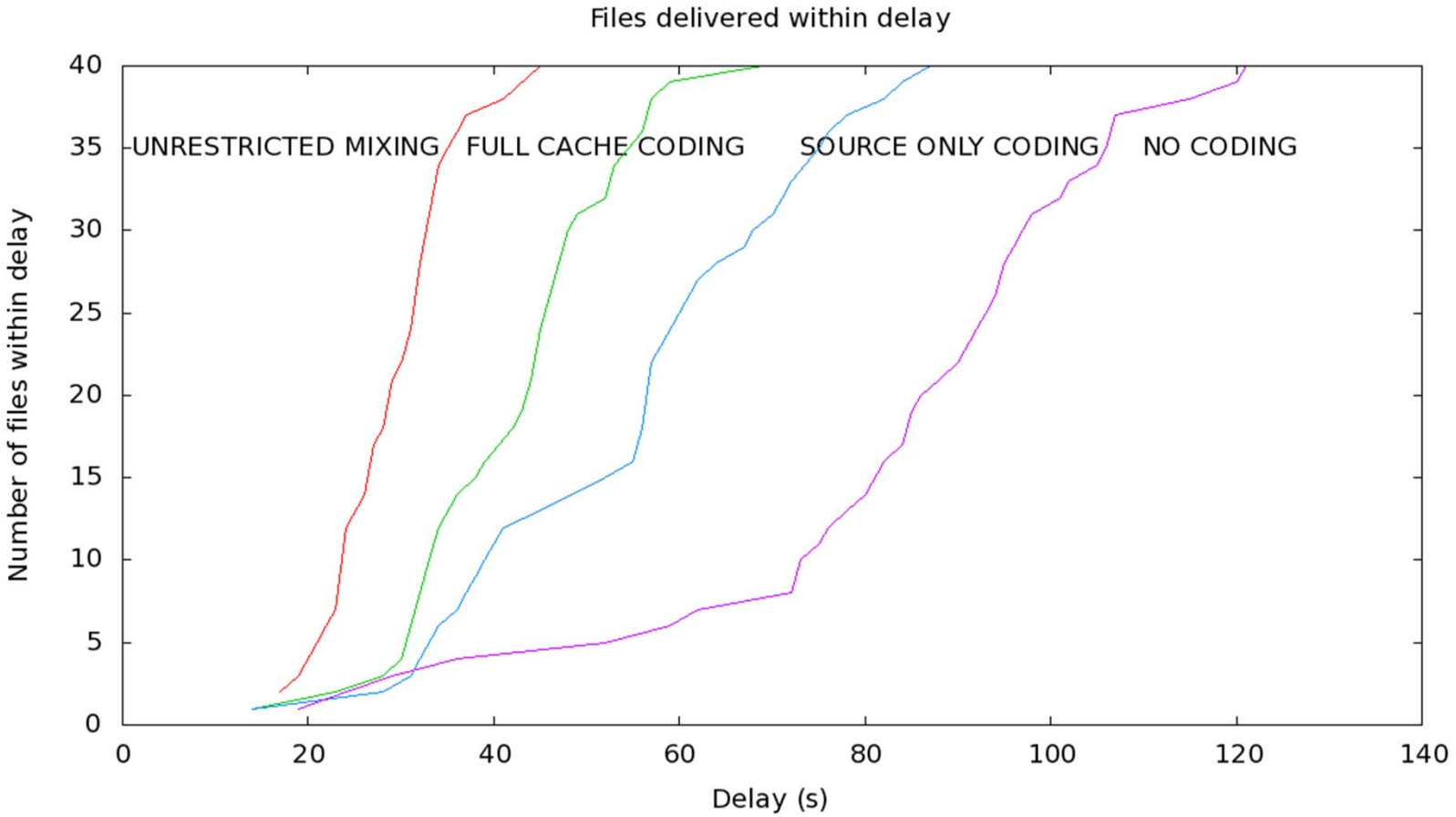
Static Scenario - Corridor Model



Single source/single destination

30% packet loss on links

Corridor scenario – Files Delivered within deadline



Single source/single destination
30% packet loss on links

ICEMAN (Information CEntric Mobile Ad-hoc Networking)

- DARPA CBMEN Project led by SRI (2012-14)
- Hybrid ICN scheme:
  - flooding of interests (a la CCN), and;
  - epidemic dissemination of int. and content (like Huggle)
- Implemented in the Haggle framework
- Goal: deliver situation awareness content to teams of mobile agents (soldiers, tanks, etc)
  - Intermittent connectivity, heavy interference, loss
  - Mobile agents cooperatively download
  - Cache coding is applied

ICEMAN Demo June 2013

Network Coding for Content-Based Intermittently Connected Emergency Networks

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ICEMAN Demo (cont)

DEMO Experiment

- Android Nexus S phones
- Topology: 10-node cluster
- nine subscribers and one publisher
- The publisher published six files with sizes ranging from 43.9 KB to 354 KB, staggered by 25 seconds every 90 seconds.

10 node Test bed results

Transport	% Delivered	Delay (s)
BCAST-CODING	95.57	19.5925
BCAST-NOCODING	95.43	35.6922

Conclusions

- ICN caches offer unique NC opportunities
  - Full cache blocks can be signed after coding
  - No repudiation, no pollution attacks
  - Eliminate need for expensive Homomorphic signatures (still prohibitive for mobile phones)
- Cache code performance approaches unrestricted code performance
- Future studies will focus on civilian applications, eg VANET downloading and file sharing