Cache and Forward Architecture

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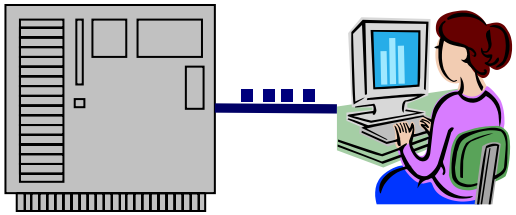
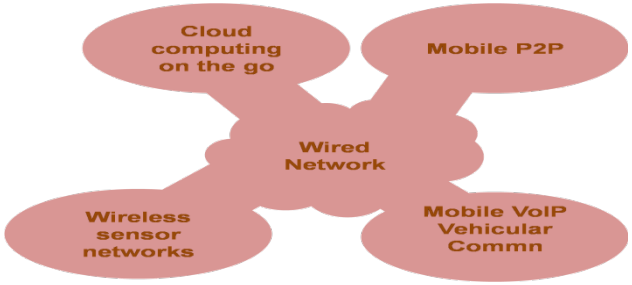
Motivation

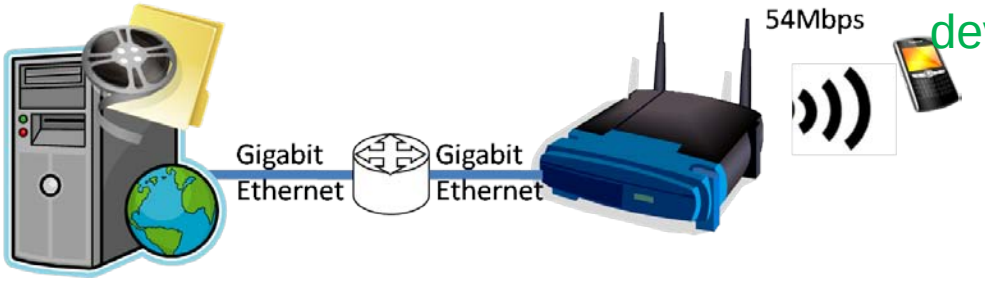


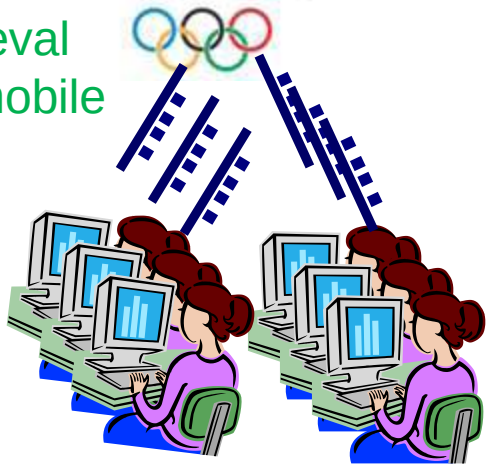
Conversation between computers connected by wires

Wired Network



Large content retrieval using wireless and mobile devices





Wireless and Video will be the key drivers for Future Internet

- Wireless has overtaken wired as the primary mode of connectivity to the Internet
  - **500M Internet-connected server/PC's vs. >2B cell-phones; 400M Internet capable**
  - **New types of wireless data devices: Blackberry, PDA, iPoD**
  - **Sensor deployment just starting: ~5-10B units by 2015**

- Variety of Wireless Network Usage Scenarios would impact Future Internet design
  - Mobile Data applications
  - Multi-Hop Wireless Mesh networks
  - Sensor networks
  - Vehicular networks
  - Info-stations

- Content (video) distribution and sharing is the most dominant application in terms of bw consumption on the Internet today and may be for the foreseeable future
  - YouTube hosts over 6M videos, growing at about 20% per month
  - Requires 45 TB of storage, several million $ worth of bw/month to transmit
  - Total time spent watching YouTube videos since it started last year is 9,305 yrs!
  - Most popular items get an especially large percentage of the traffic
  - Cameras are everywhere (cellphones, video surveillance, handycams etc.)
  - Hundreds of TV channels on the Internet and growing
  - MySpace last year generated an astounding 31.5 billion page views per month

Focus on Efficient Dissemination of Content to-and-from Mobile Wireless Devices

We don't want to talk anymore. We just want to see the movies!

Drivers for Future Internet design

Wireless Network Usage Scenarios	Characteristics	Impact/Requirements
Mobile Data Wireless Mesh	Time-varying link (capacity, error rate)	Opportunistic transport Cross-layer protocol design
Vehicular Network Info-station	Intermittent connectivity, High bw	Opportunistic transport Cache and Carry
Sensor Networks	Low CPU/Memory/Power Intermittent connectivity, Low bw	Opportunistic transport, Computation at nodes, Data driven networking

Other Trends	Characteristics	Impact/Requirements
Proliferation of video (YouTube)	High bandwidth and storage Popularity of some clips	Efficient Transport (Caching)
Sharing of content (Myspace, Facebook)	Content (music, photos, video) is bulk of traffic	Efficient Sharing (Caching)

Caching and Opportunistic Transport are emerging as key themes

Semiconductor Memory for $50: 256MB in 2000; 1GB in 2004; 5GB in 2006, >16GB in 2010

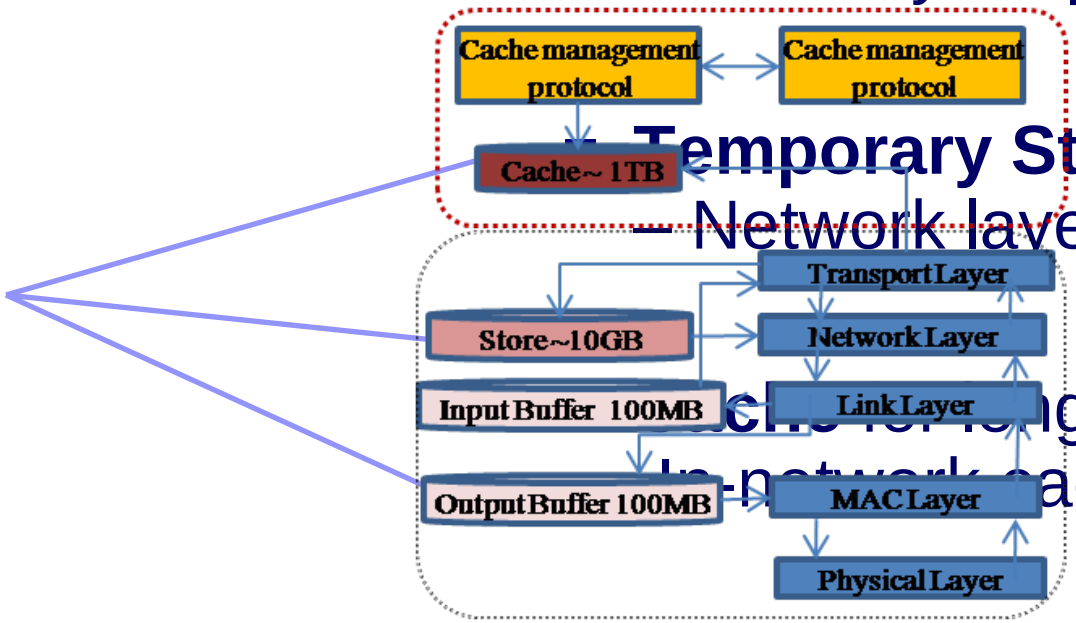
Storage is cheap and plenty of Processing available at low cost

Cache and Forward Router

Because storage is cheap and getting cheaper

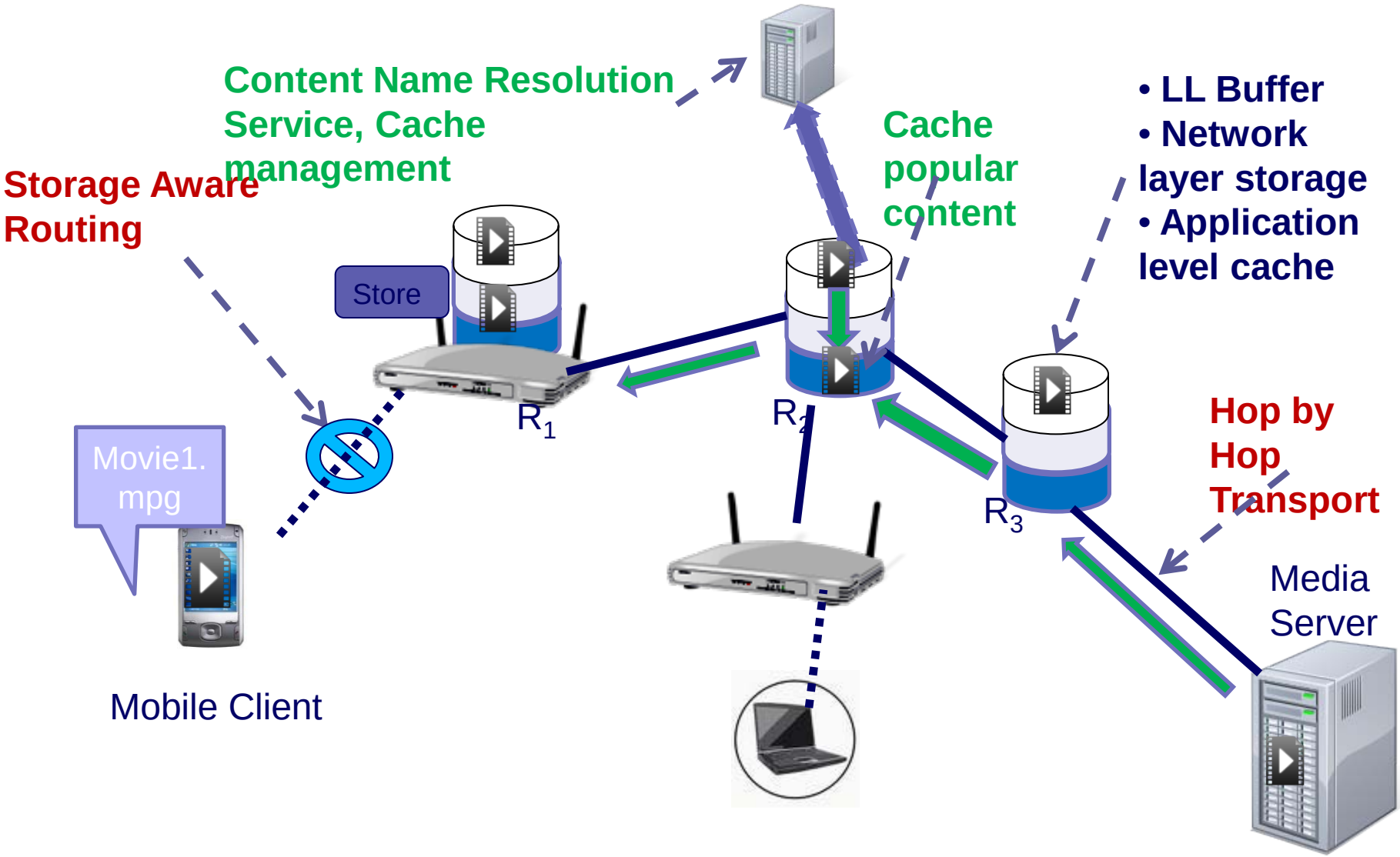
Lots of Storage Space

- **Buffers** to store content in transit
  - Link layer optimization
- **Temporary Store** for short term
  - Network layer optimization
- Caches for long term storage
  - In-network caching
- **Potentially a distributed data center!**

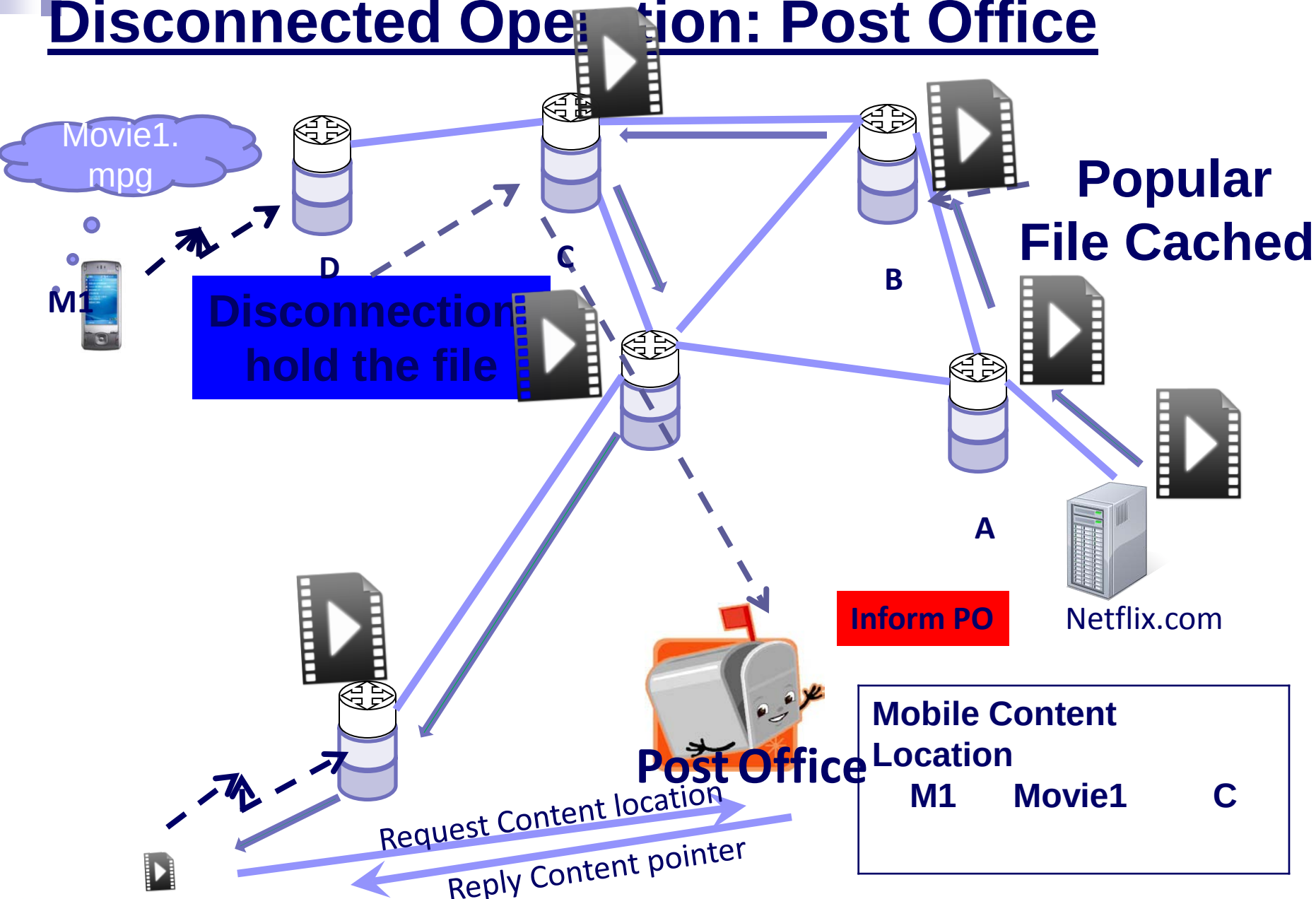


In an ideal world we replace all routers with CNF routers. In real world incremental replacement is feasible.

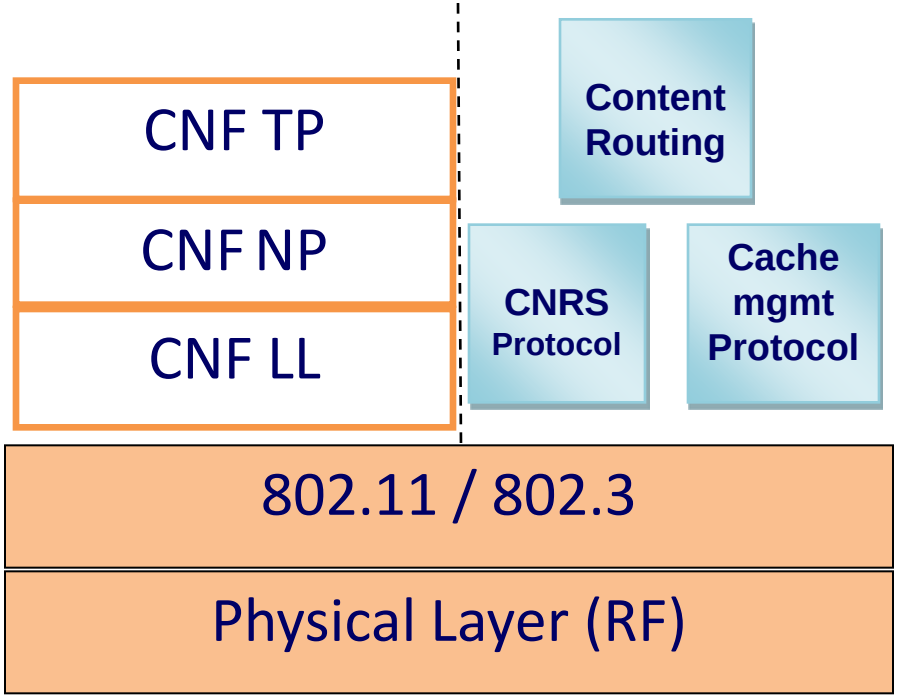
Cache and Forward (CNF) Network Architecture



Disconnected Operation: Post Office



CNF Protocol Stack



Data Plane Services

-- Reliable Link protocol
-- Storage Aware Routing
-- Hop by hop transport

-- Content Pull *Get(M)*
-- Content Push Unicast *Send(M,D)*
-- Content Push Multicast *Send(M,[D1,D2…Dn])*

Control Plane

-- Content Name and Resolution Service
-- Cache management

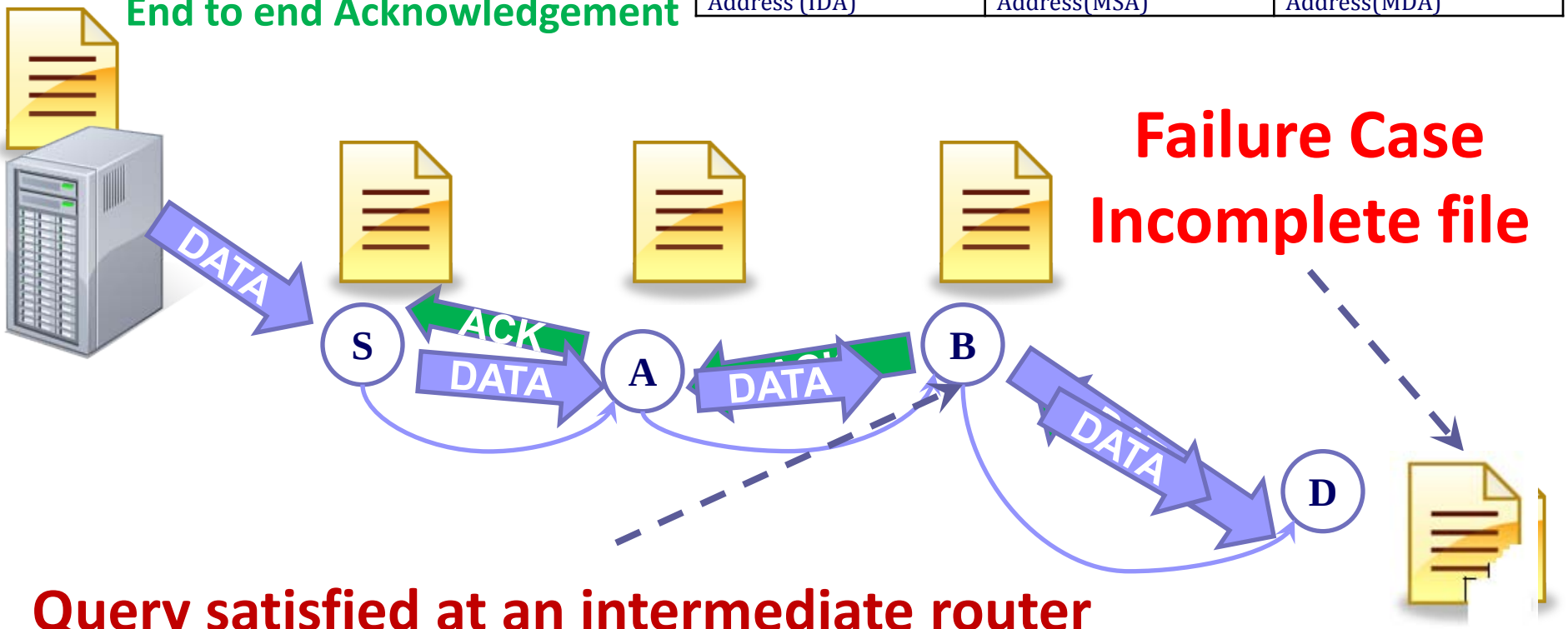
CNF Transport

Forward the content one hop at a time instead of packet by packet and end to end streaming

Packet Format

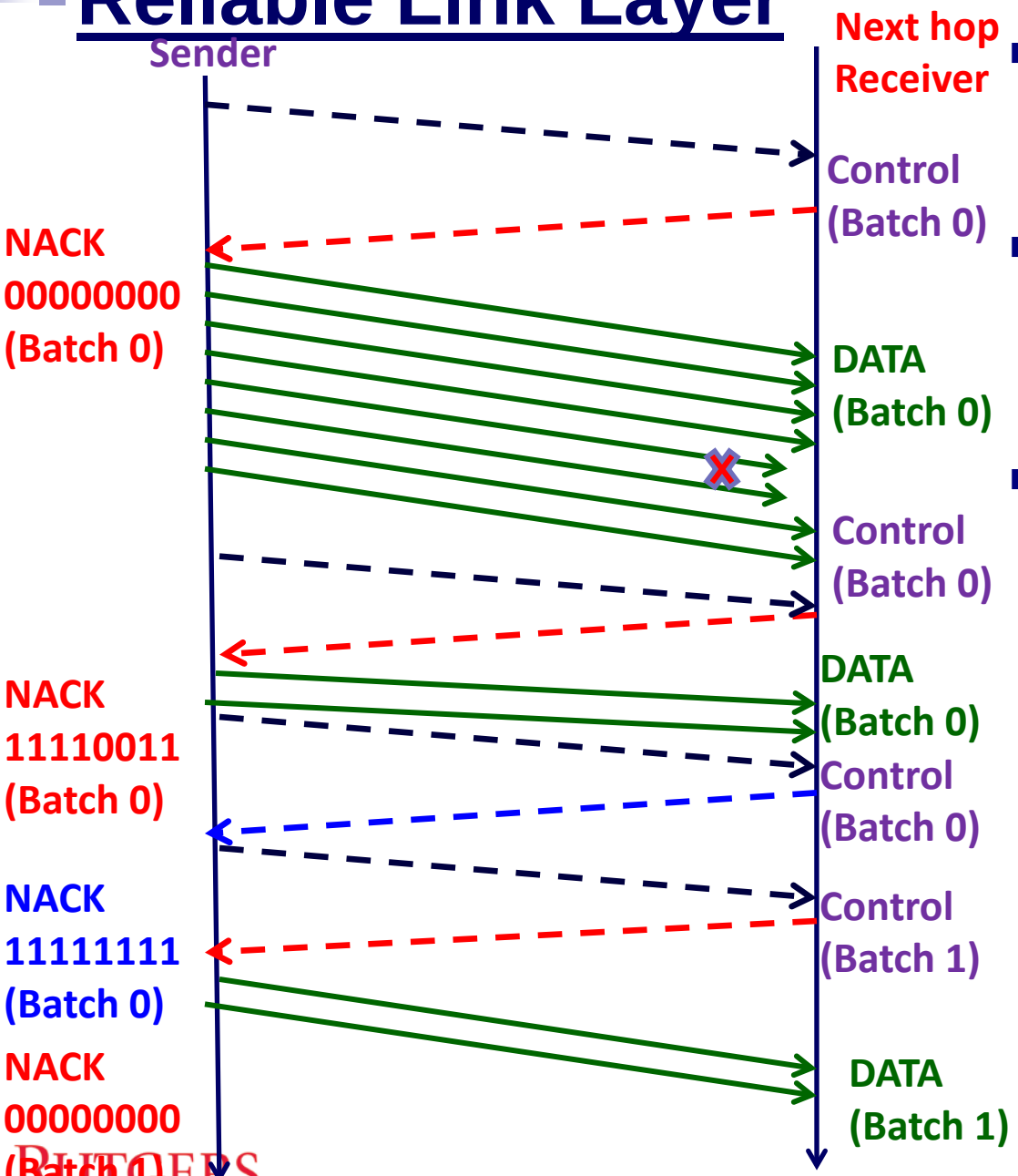
Packet Length	Packet Sequence Number	Hop Count
Content ID (CID)	Type of Service (TOS)	Expiration Time (ET)
Original Source Address (OSA)	Final Destination Address (FDA)	Intermediate Source Address(ISA)
Intermediate Destination Address (IDA)	Mobile Source Address(MSA)	Mobile Destination Address(MDA)

End to end Acknowledgement



Query satisfied at an intermediate router

Reliable Link Layer



- Fragment large files into batches of smaller packets.
- Transmit each batch to the next hop
- Exchange ACKs, NACKs and retransmit to achieve reliability

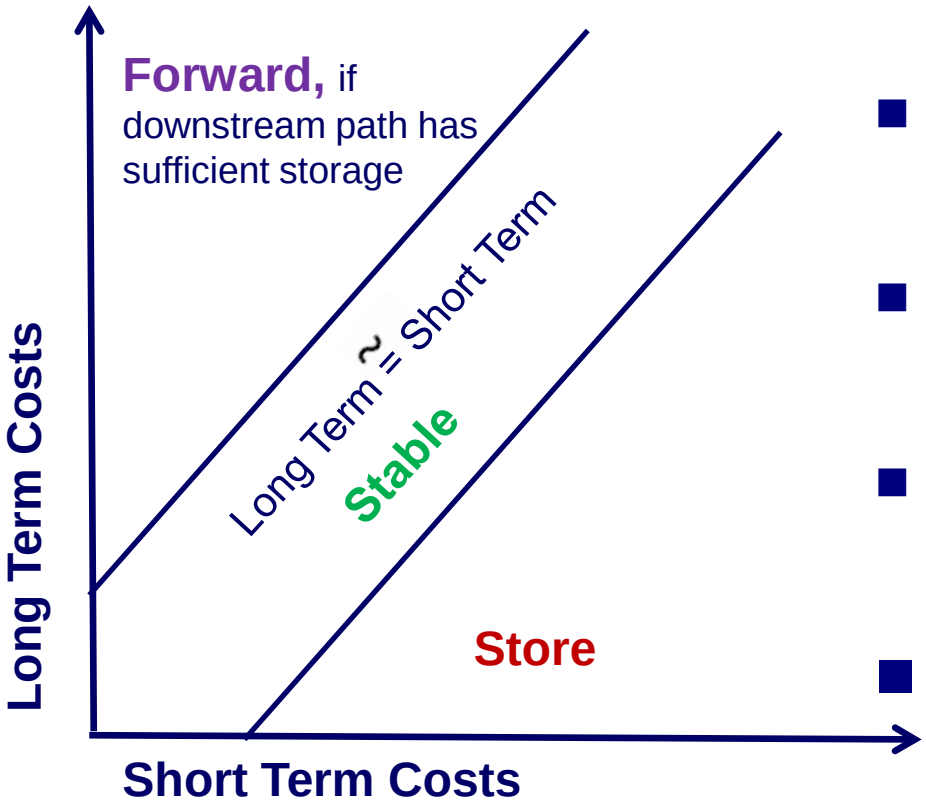
Storage Aware Routing

Use History and Storage

- Storage
  - Available storage at all other routers in the network
- Short Term Cost
  - Instantaneous value of the link costs
- Long Term Cost
  - Historical representation of the link cost metric over a longer time period
    - Moving average of short term costs

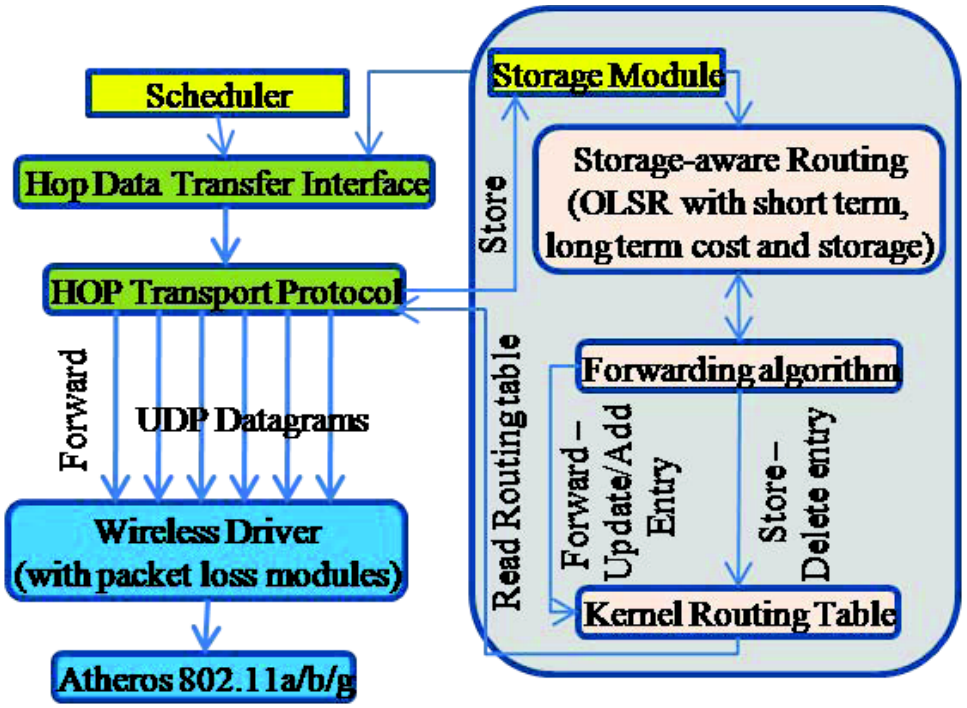
The cost metric should have a variable component– link speeds, queuing delays, contention

Two Dimensional Decision Space

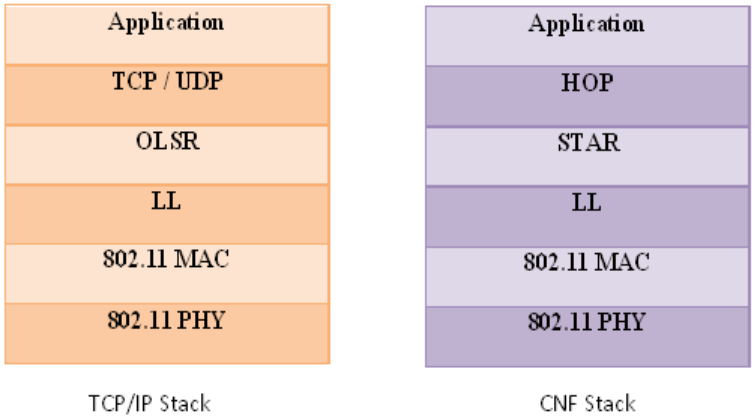


- Stable region
  - 0.9 < SCost/Lcost < 1.1
- Store region
  - Scost/Lcost > 1.1
- Forward region
  - SCost/Lcost < 0.9
- Min. available storage along downstream path > Storage threshold

Implementation on ORBIT



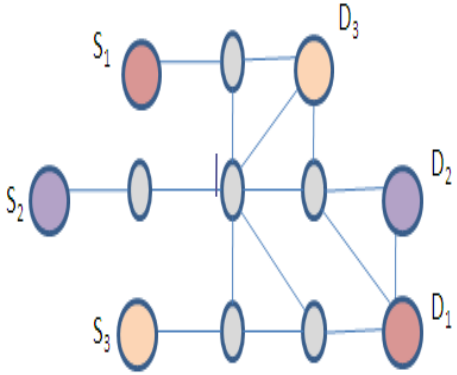
Software Architecture



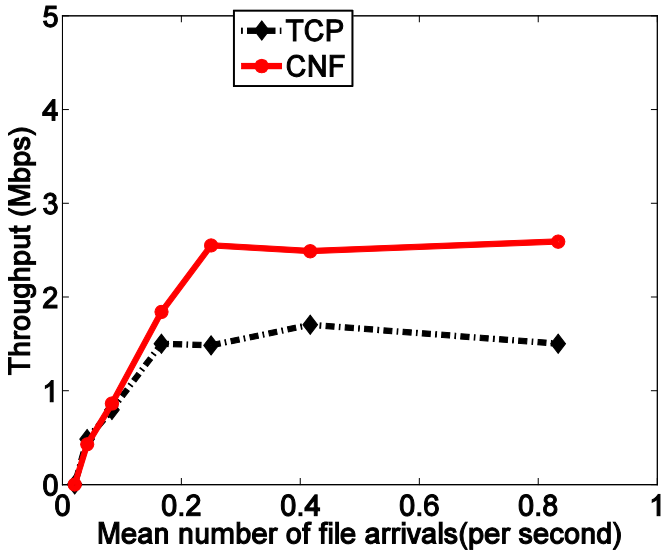
Comparison protocol Stacks

CNF Comparison with TCP

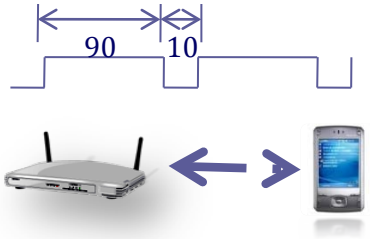
- Poisson arrival process
- File size 500KB



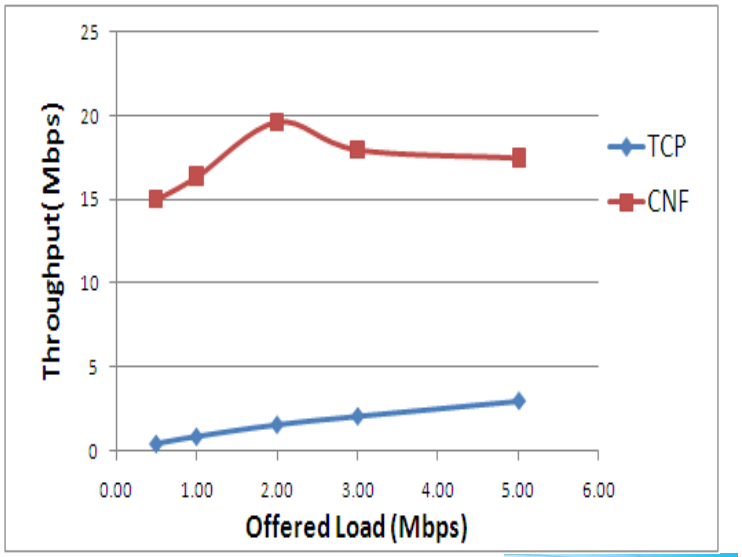
- 3 simultaneous flows
- 100 file transfers
- Average throughput



- CBR traffic
- Measure average streaming throughput



- Single hop topology
- On- Off scenario, 40-400 sec



Summary

- For multihop wireless static scenarios, throughputs provided by CNF found to be 30% higher than TCP
- With mobility and time varying link disconnections, CNF performance has a clear advantage
- **Future Work:** Experiments with other mobility models, traffic models and topologies (including wired backbone), WiMAX and mobile vehicular nodes for a more complete evaluation.
- **Future Work:** Implement a full blown CNF architecture including caching, addressing, content naming