Multi-Path Protocol for Big Data Transfer

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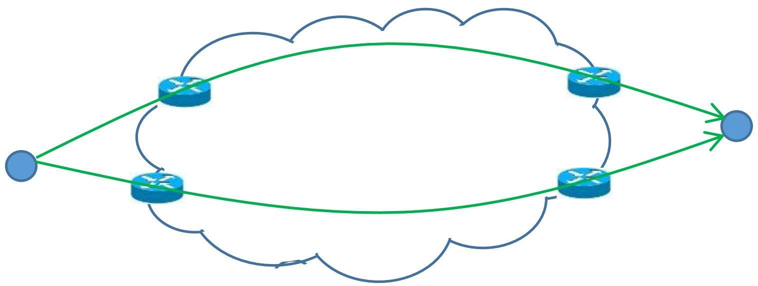
Outline

- How can we move data faster by providing multi-path transfer capability through the network
- What can an ICN architecture like NDN offer (compared to IP)
- Show that it can be done easier and more efficiently with NDN than with IP
- Describe our implementation and its performance

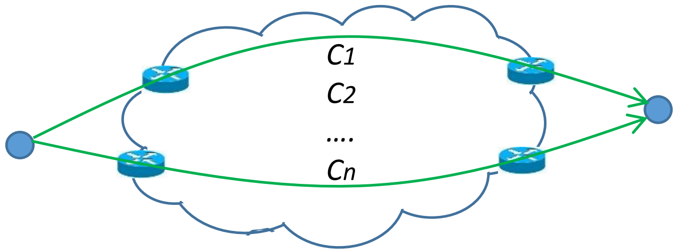
Multi-path transfer

- Large data volume can come from either
  - small number of large data files (such as from scientific big data from previous talks), or
  - large number of small data objects (such as from video content distribution),
  - even though a large data volume in both cases
- To support big science data we're interested in the problem of maximizing transfer rate (hence minimizing transfer time) when moving large data files
- Multi-path transfer uses multiple paths between two endpoints
  - network resources on all paths appear to the endpoints as a single pooled resource
  - dynamic scheduling (coordinated congestion control) used to split data traffic across the available paths
- Benefits to user
  - Higher throughput: due to pooled resources
  - Improved resilience to link or node failure (if we lose resources on one path we still have the resources of other paths)

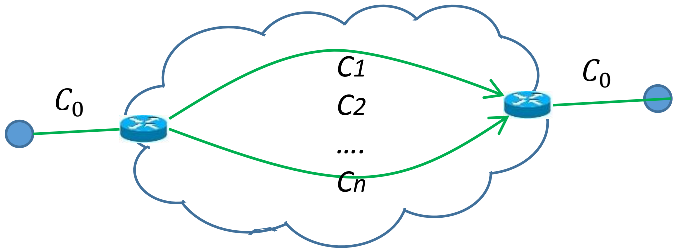


Multi-path throughput

- With fully disjoint paths,
  - we can achieve $C = \sum_{i=1}^{n} C_i$

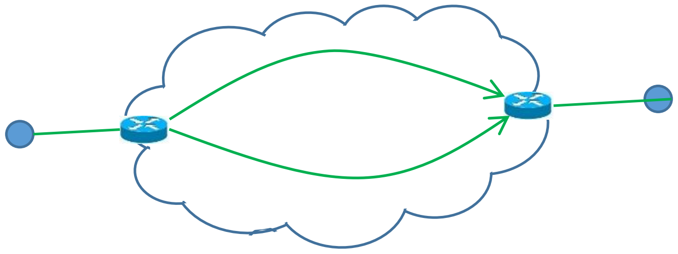


- With partially disjoint paths
  - If $C_0 \geq \sum_{i=1}^{n} C_i$, then as if fully disjoint (from throughput point of view)
  - Still useful when $\max(C_i) < C_0 < \sum_{i=1}^{n} C_i$, can still get some benefit from multi-path

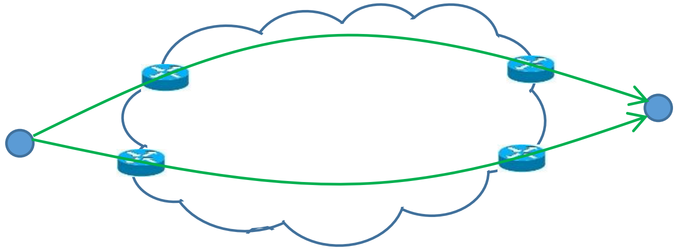


How can we get multi-path capability

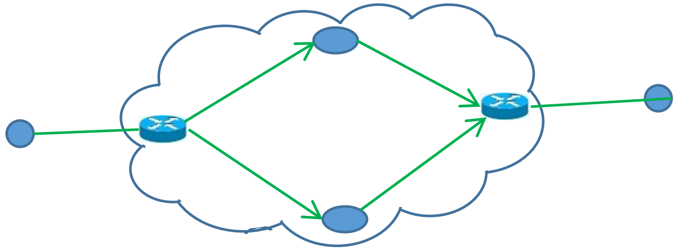
- [1] Network-controlled multi-path
  - No end-point involvement (end-user with single physical network connection)
  - Network splits end-user traffic into multiple paths

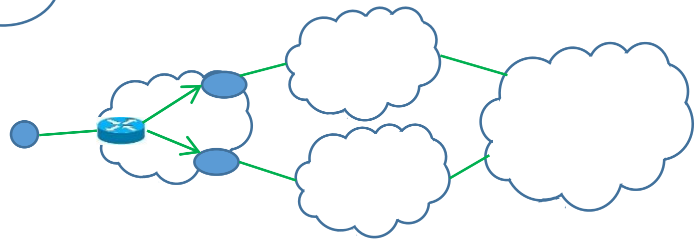


- [2] User-controlled multi-path through interface selection
  - End-point is multi-homed (with multiple physical access links)
  - Number of paths up to number of physical access links
  - No network involvement (user splits traffic)

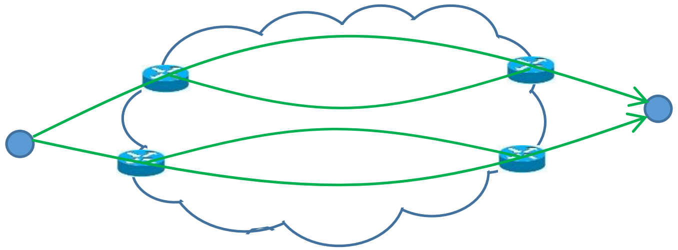


- [3] User-controlled multi-path through transit selection
  - User selects transit points (topologically diverse) for multi-path



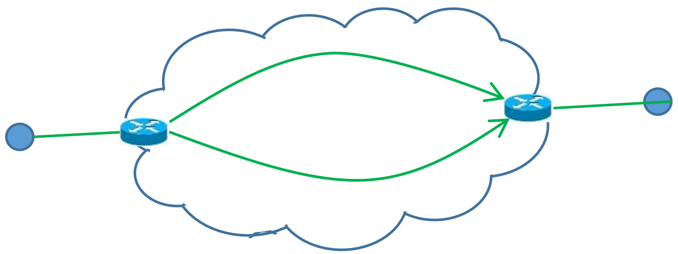


- Combinations are also possible
  - [1]+[2]
  - [1]+[3]
  - [2]+[3]
  - [1]+[2]+[3]



Network-controlled multi-path

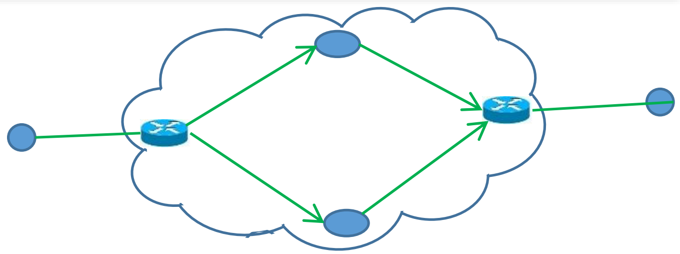
- In IP networks, forwarding is always along the shortest path
  - If multiple such paths exist, equal-cost multi-path (ECMP) routing can be used for load balancing over them
  - To avoid IP routing loops only paths with the minimum routing cost can be considered
  - Limited number except in some regular & dense topologies (data centers)
- ECMP works at the flow level (5-tuple flow granularity)
  - but we need to split one big flow into sub-flows
  - multiple IP addresses per interface needed for multi-path tcp to work in this case (up to # ECMP paths)



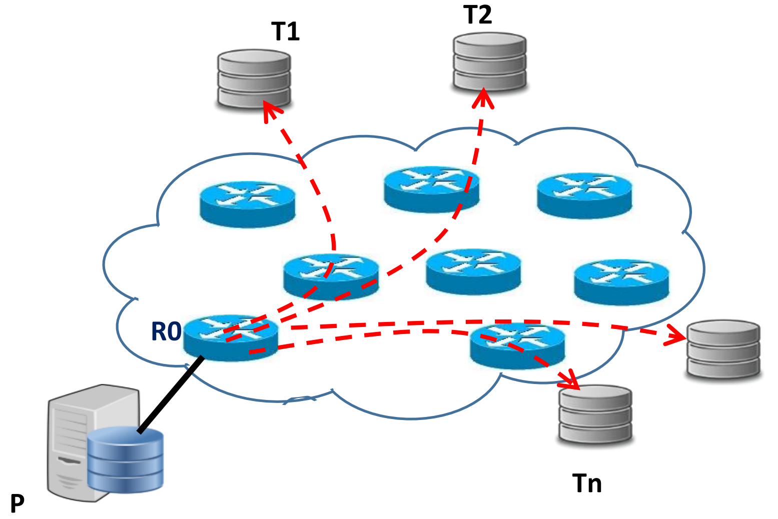
- In NDN networks, multipath is easy and readily available
  - Through Interest-forwarding strategy (can split traffic arbitrarily)
  - Built-in loop detection mechanism allows exploring any path (not just shortest paths)

Our approach

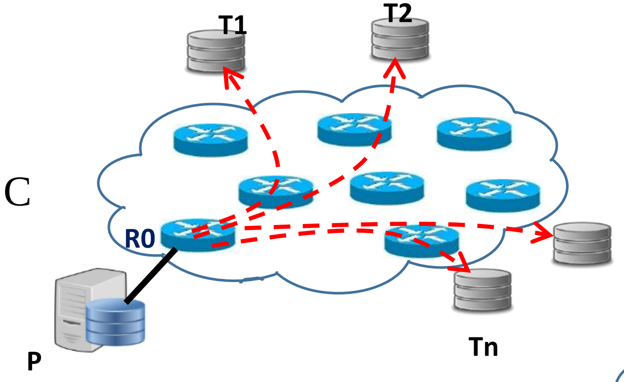
- Our approach is based on transit node selection and we made an implementation based on this approach
- Partly due to the fact that we started with the following problem:
- Given large data object stored at customer location P, transfer it as fast as possible to cloud storage
- Possible use case:
  - Customer logs in to the portal of its cloud service provider (CSP) to initiate transfer of a data object
  - Provides the name of the data object **/NIST/MML/archive1**
  - CSP selects a set of diverse locations and triggers each storage location to start downloading objects with the given name
  - wildcard character (/NIST/MML/archive1/*) meaning that it is ready to accept the next data packet without specifying any particular one [“exclude” option can be used instead]
    - P will reply with the next non-transmitted data packet
  - For reliable delivery, the index of last received packet is appended to names in Interests
  - Producer keeps track of lost Data packets for retransmission

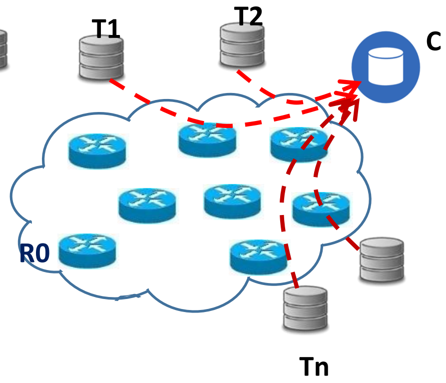


I: /NIST/MML/archive1/*/lastBlockID
D: /NIST/MML/archive1/*/currentBlockID

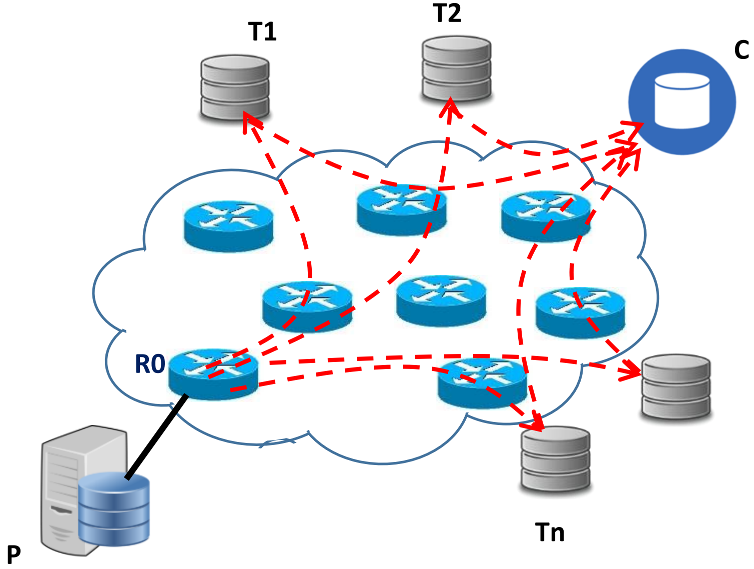


- Distributed Transfer Protocol (DTP)
  - each location will have a subset of the original data object (not necessarily a contiguous in-order block)
  - if needed, can be followed by another protocol to consolidate at location C
  - Can be adapted for Hadoop map/reduce application



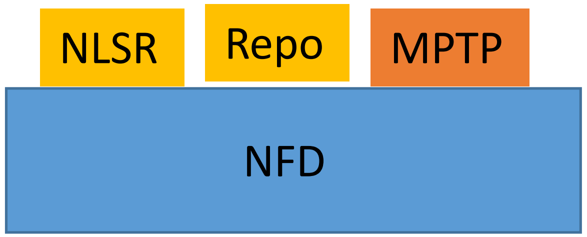


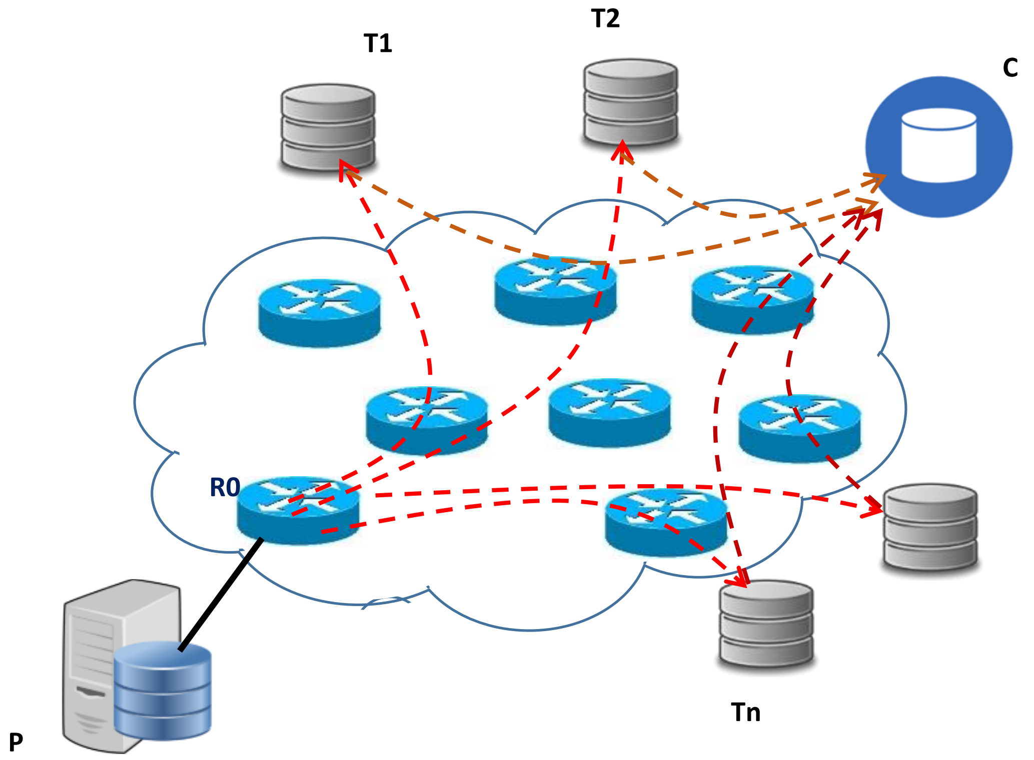
- Next step: Multi-Path Transfer Protocol (MPTP)
  - performs end-to-end simultaneous transfers through a selected set of locations
  - simpler than DTP as only C needs to keep track of received/lost Data packets (P needs to do this in DTP)



NDN Multi-Path Transfer Protocol ndnMPTP

- CSP instructs C to initiate simultaneous (parallel) transfers of the data file **/NIST/MML/archive1** from producer P through a selected set of transit nodes T1, T2, …, Tn (with names denoted /T1 , /T2, …, /Tn)
  - ndnMPTP running at each of the nodes
  - All /Ti names are reachable (advertised in routing)



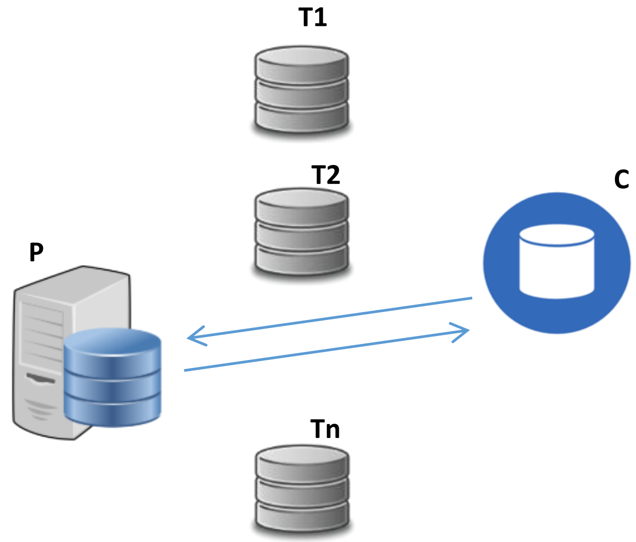


ndnMPTP – step0

- First Interest generated at C with the name
  - **/NIST/MML/ndnMPTP/archive1**
- ndnMPTP running at P will return the first data block in a Data packet with a specification of FinalBlockID as part of the MetaInfo

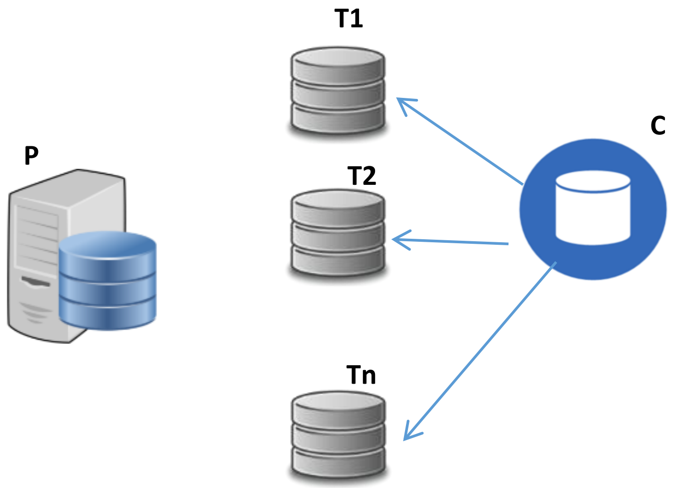
```
Data ::= DATA-TLV TLV-LENGTH
           Name
           MetaInfo
           Content
           Signature
```

```
MetaInfo ::= META-INFO-TYPE TLV-LENGTH
               ContentType?
               FreshnessPeriod?
               FinalBlockId?
```

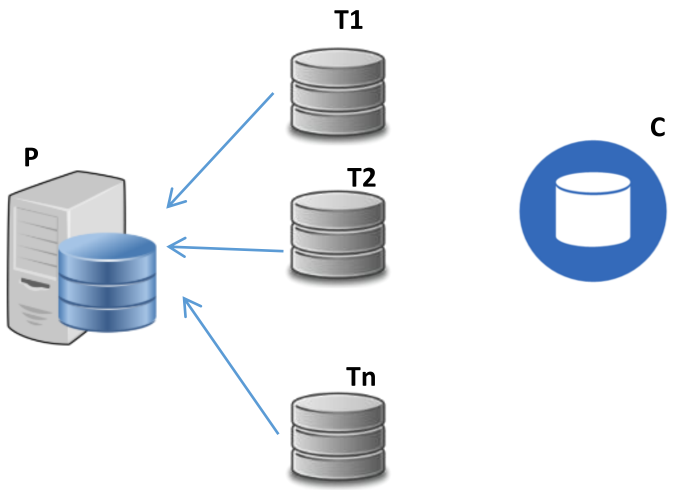


ndnMPTP – Interest

- Interests are generated at C for each Ti with the name
  - **/Ti/ndnMPTP/NIST/MML/ndnMPTP/archive1/BlockID**
- Consecutive BlockIDs are requested up to FinalBlockID
  - Subject to retransmission of lost blocks and flow control at C

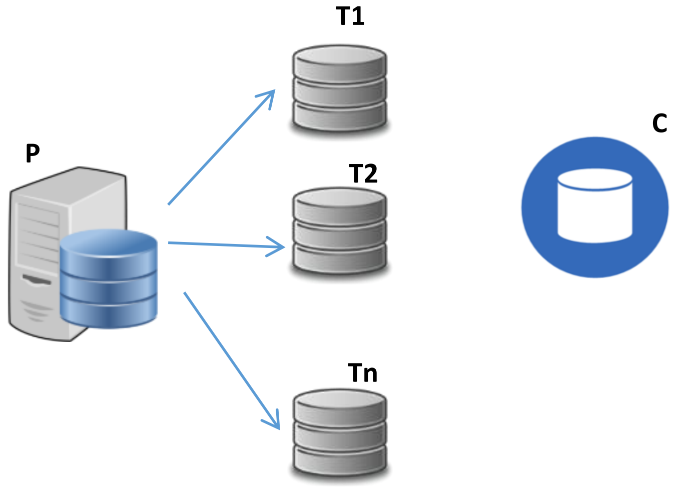


- Interest processing at Ti
  - Send new Interest with name **/NIST/MML/ndnMPTP/archive1/BlockID**
- Interest processing at intermediate node
  - Standard NDN processing

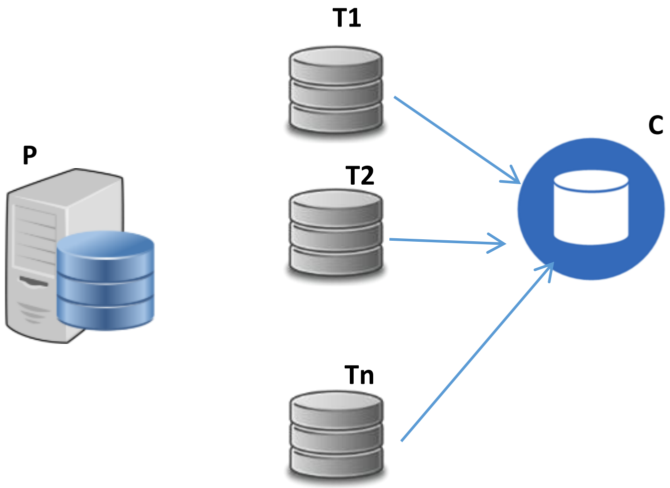


ndnMPTP – Data

- For each Interest, deliver corresponding data block
- Name in Data packet is
  - **/NIST/MML/ndnMPTP/archive1/BlockID**



- Data processing at intermediate nodes
  - At Ti append /Ti/ndnMPTP to name : **/Ti/ndnMPTP/NIST/MML/ndnMPTP/archive1/BlockID**
  - Other nodes: normal NDN processing



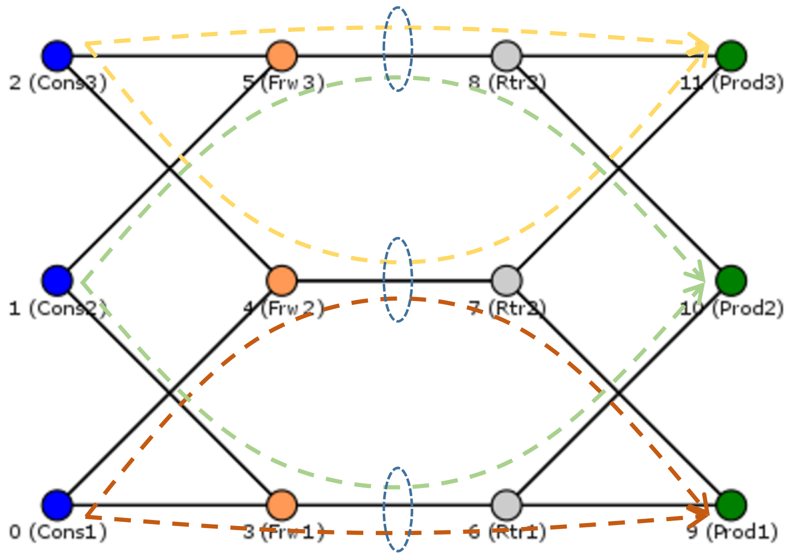
At Consumer:

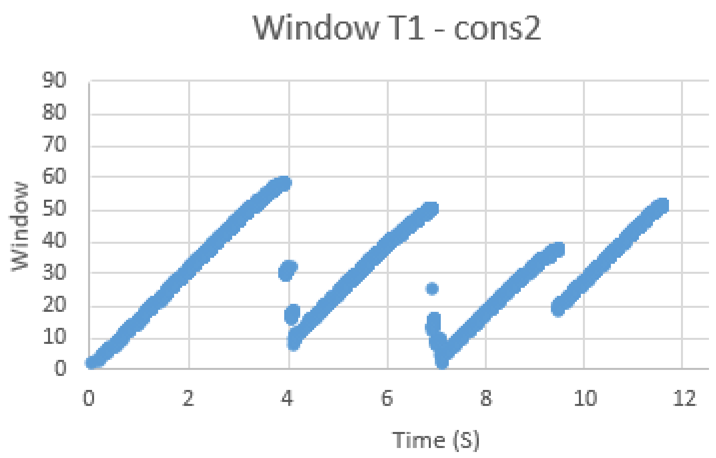
	Outstanding/inflight (per Ti)	Window (per Ti)	Round Trip Time (per Ti)
On_Data (Rcv)	Oi=Oi-1	Wi=Wi+AIF/Wi (+1 per RTT)	RTT_i=T_sent – T_current Compute average/deviation
On_Interest (Send)	Oi=Oi+1		Set Timeout for Interest Record T_sent
On_Timeout (no Data within TOi)	Oi=Oi-1	Wi=Wi*MDF (1/2)	Retransmit Interest

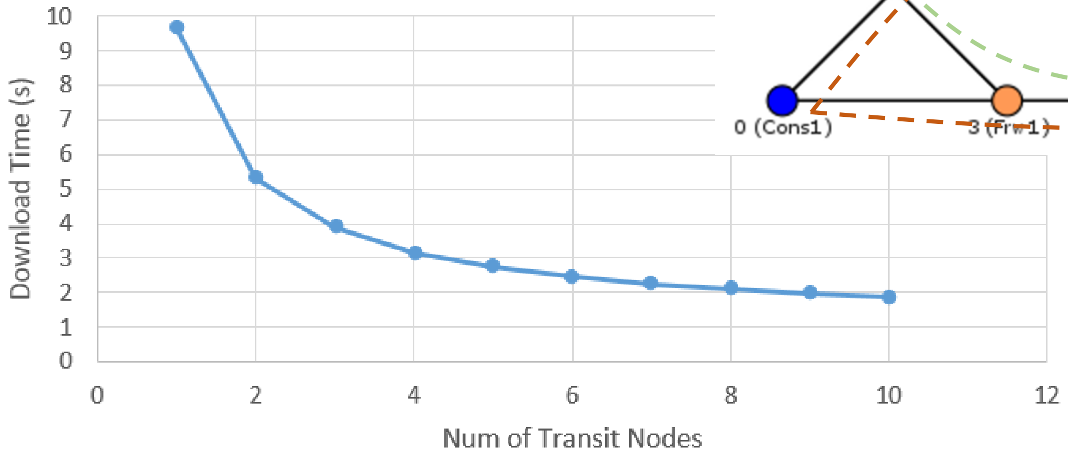
Per Ti :
Initialize TO
subsec. up to 1 sec
When first RTT is measured set:
RTTave=RTT
RTTdev=RTT/2
Whenever a subsequent RTT is collected set:
RTTdev=b*|RTTave-RTT| + (1-b)*RTTdev [1/8]
RTTave= a*RTT + (1-a)*RTTave [1/4]
When sending Interest after first RTT measurement
TO= RTTave + K*RTTdev [4]

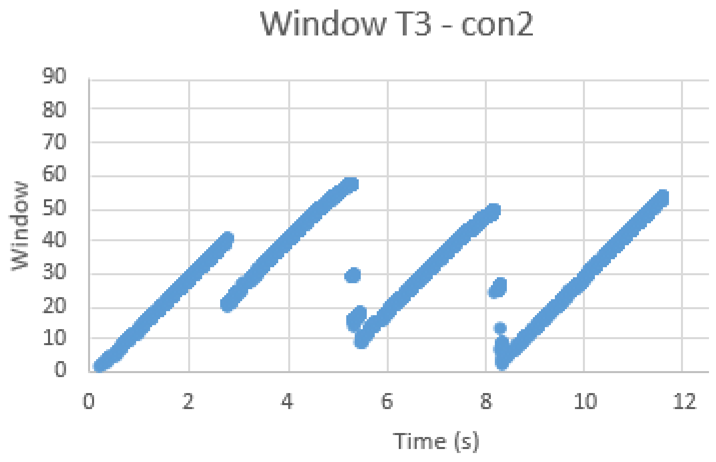
Evaluation

- Preliminary simulations using ndnSIM
- Implementation using NDN-Cxx libraries
- Still ongoing









Next steps

- Did not yet activate multi-path feature in the NDN strategy
  - To find out how it will change the dynamics of TC
  - Expected to provide more benefit through additional load balancing

- NDN multipath congestion control
  - Better understanding (beyond single path)

- Testbed evaluation
  - Code on Github
  - NIST gateway node on NDN testbed
  - Plan to test/collect traces on testbed