Department of Electronics, Information, and Bioengineering

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Optimal Content Placement in ICN Vehicular Networks

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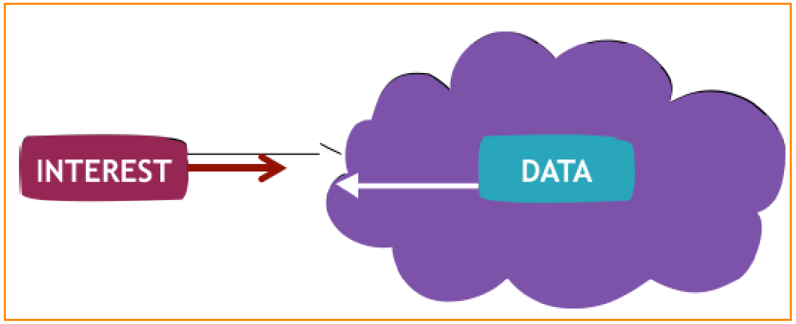
Outline

- ✗ Main problem of user mobility:
  - ✗ intermittent connectivity → loss of packets.
- ✓ In ICN, communication follows request/response model:
  - ✓ the user sends an Interest for the desired content
  - ✓ the network chooses the best node from which delivering the content.
- ✓ When consumer moves, seamless handover is achieved by reissuing the interest message from the new location.
- ✓ In an ICN, the contents are stored in multiple nodes.

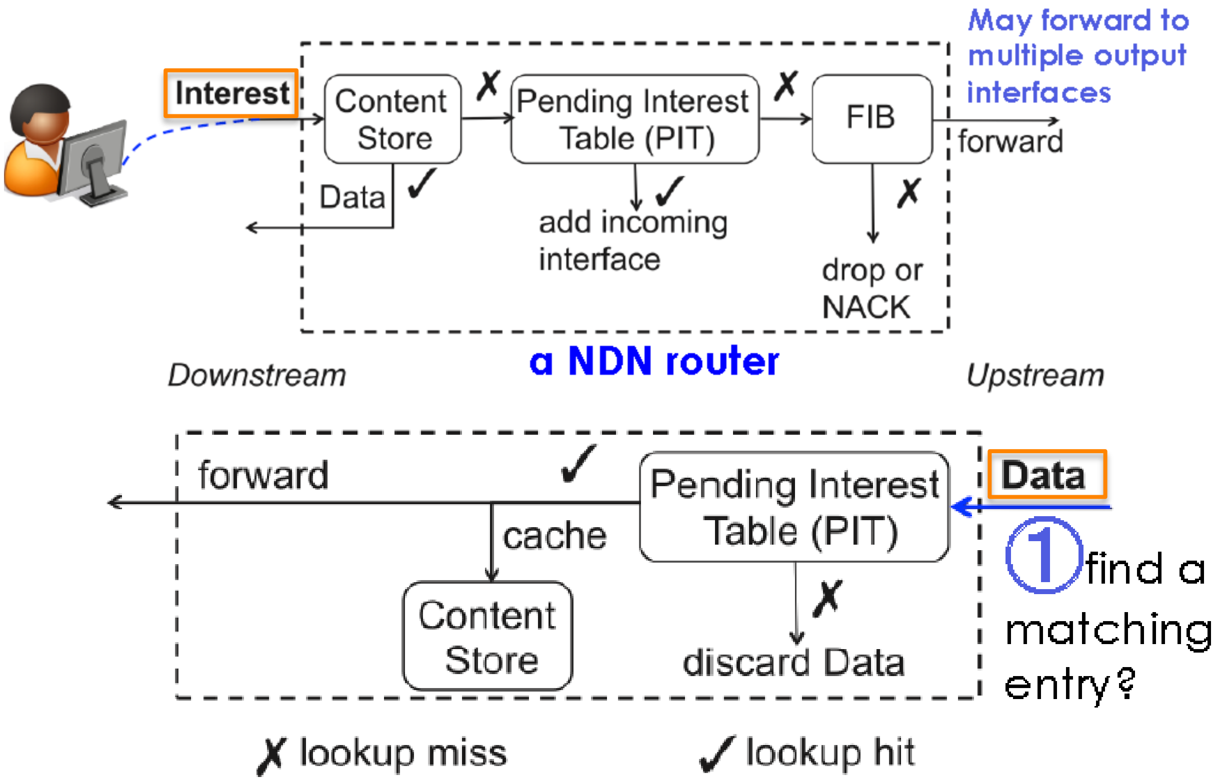
☞ We give an ILP formulation of the problem of optimally distributing contents in the network nodes.

NDN communication model

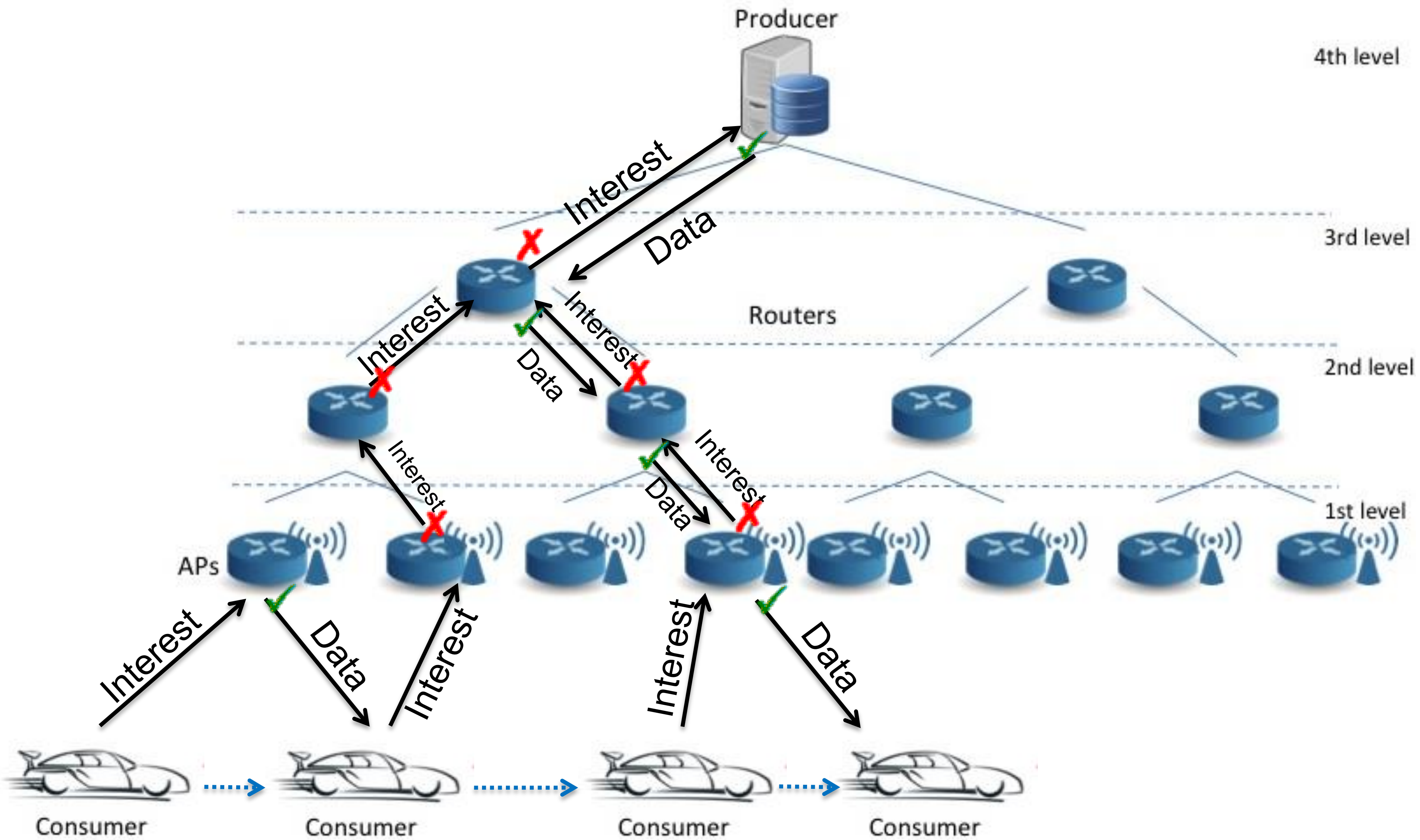
- Consumer sends Interest packet



- Whoever has the matching Data packet can reply



NDN and V2I



Producer
4th level
Interest
Data
3rd level
Routers
Interest
Interest
Data
2nd level
Interest
Interest
Data
1st level
APs
Interest
Data
Interest
Interest
Data
Consumer
Consumer
Consumer
Consumer

V2I, Contents and Retrievability

- A user entering the area asks for a content
- Each content is segmented in chunks, so the vehicular user can retrieve different parts across different APs.
- A content is successful retrieved if the user moves out of the area with all the chunks of the content.
- We formulate the ILP problem of optimally deploying the content chunks in the network nodes so as to maximize the probability that a vehicular user succeeds in retrieving a chosen content from the network.

V2I Scenario for ICN

- **Sets:**

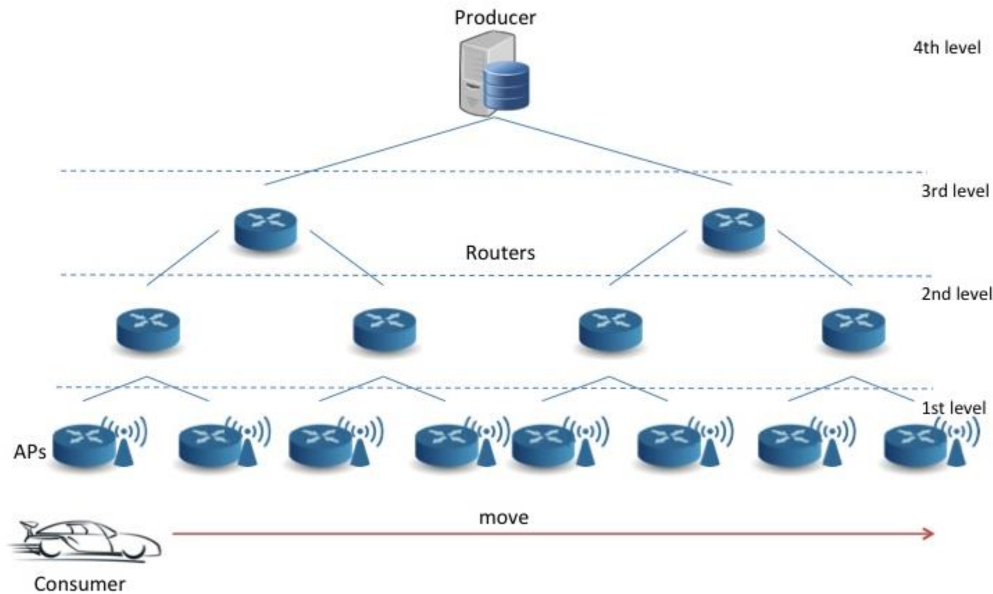
Access Points: $i \in \mathbb{I} = \{1, \ldots, I\}$
Contents: $j \in \mathbb{J} = \{1, \ldots, C\}$
Paths: $v \in \mathbb{V} = \{1, \ldots, V\}$
Tree levels: $l \in \mathbb{L} = \{1, \ldots, L\}$

- **Variables:**

$X_{ijl} \in \mathbb{Z}$ integer number of chunks of content *j* cached into a content store of level *l* linked to AP *i*;

$A_{jv} \in \{0, 1\}$ boolean variable that is 1 if the content *j* is retrievable along the path *v*, 0, otherwise;

$Rec_{ijlv} \in \mathbb{Z}$ integer number of chunks of content *j* retrieved from content store of level *l* linked to AP *i* along path *v*.



$$X_{ijl} \geq 0, \;\; Rec_{ijlv} \geq 0, \;\; A_{jv} \in \{0, 1\}$$

Optimal Content Placement (I)

- Constraints:

Retrievability of a content

$$\sum_{i,l} Rec_{ijlv} \cdot m_{iv} = A_{jv} \cdot S_j \quad \forall j, \forall v$$

Limit on retrievability

$$\sum_{l} (\gamma_{ilv} \cdot Rec_{ijlv}) \leq MDB_{i1v} \quad \forall i, \forall j, \forall v$$

Maximum number of retrievable chunks

$$Rec_{ijlv} \leq X_{ijl} \quad \forall i, \forall v, \forall j, \forall l$$

Optimal Content Placement (II)

- Constraints:

Content Store capacity limit

$$\sum_{j} X_{ij1} \leq CS \quad \forall i$$

$$\sum_{i \in \mathcal{I}, j} X_{ij2} \leq CS \quad \mathcal{I} = \{1,2\},\{3,4\},\{5,6\},\{7,8\}$$

$$\sum_{i \in \mathcal{I}, j} X_{ij3} \leq CS \quad \mathcal{I} = \{1,2,3,4\},\{5,6,7,8\}$$

Link capacity limit

$$Rec_{ijlv} \leq MDB_{ilv} - \sum_{q=1}^{l-1} Rec_{ijqv} \quad \forall i, \forall v, \forall j, l = 2,3,4$$

Optimal Content Placement (III)

- Objective Function:

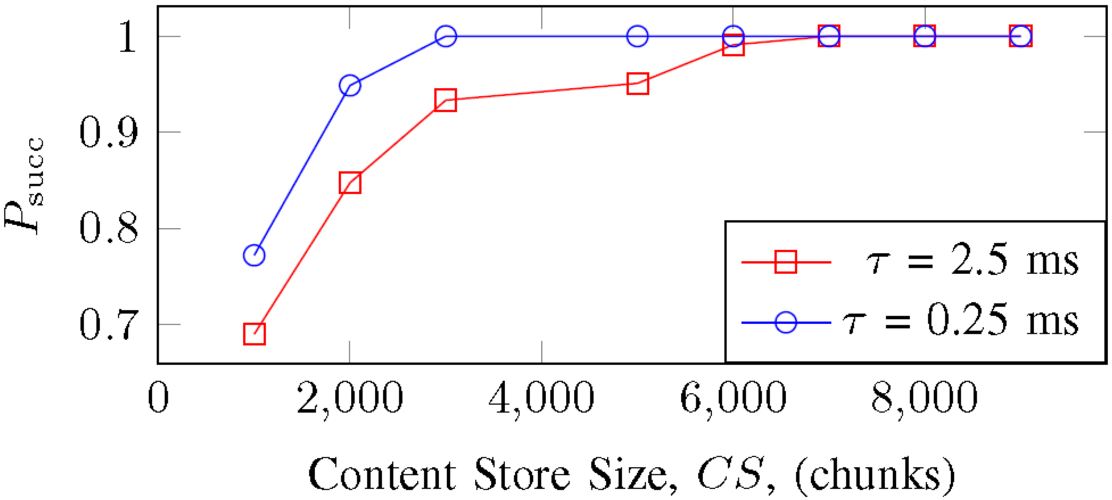
$$\max: \sum_j Req_j \sum_v P_v A_{jv}$$

- Success Probability:

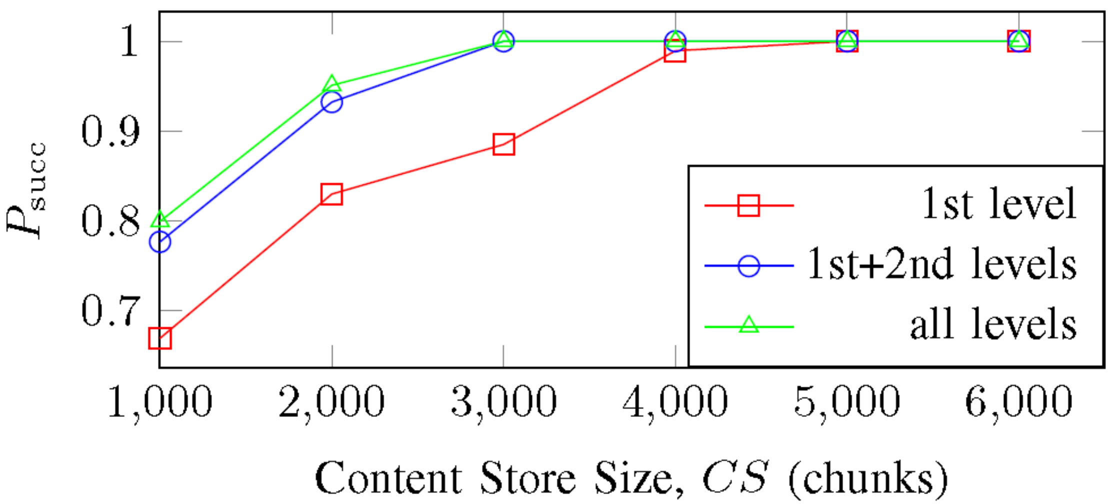
$$P_{\text{succ}} = \sum_{j=1}^{C} Req_j \sum_{v=1}^{V} P_v A_{jv}$$

Results (I)

- The success probability, P_{succ}, depends on the size of the content store, *CS*, and on link transmission latency, τ.

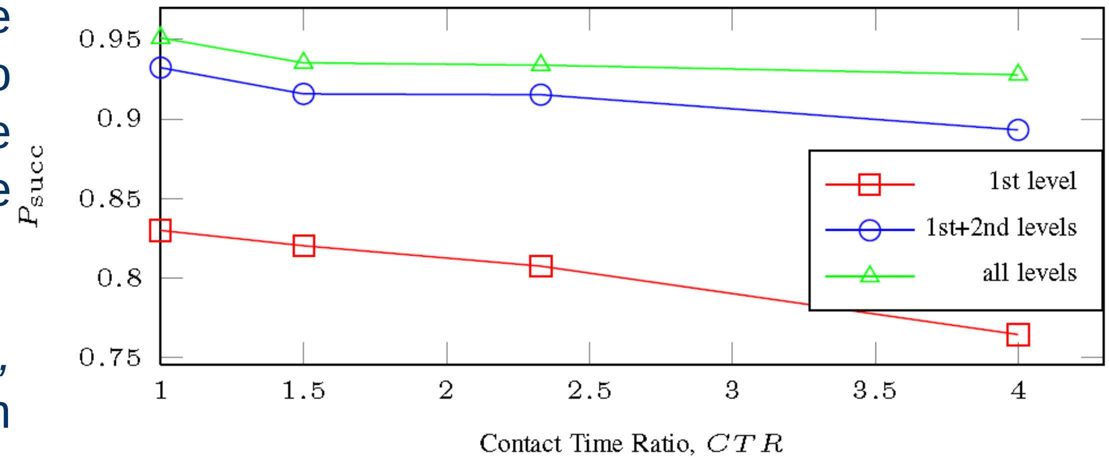


- The success probability, P_{succ}, depends also on location of content store at different levels of the tree and the size of the installed cached.



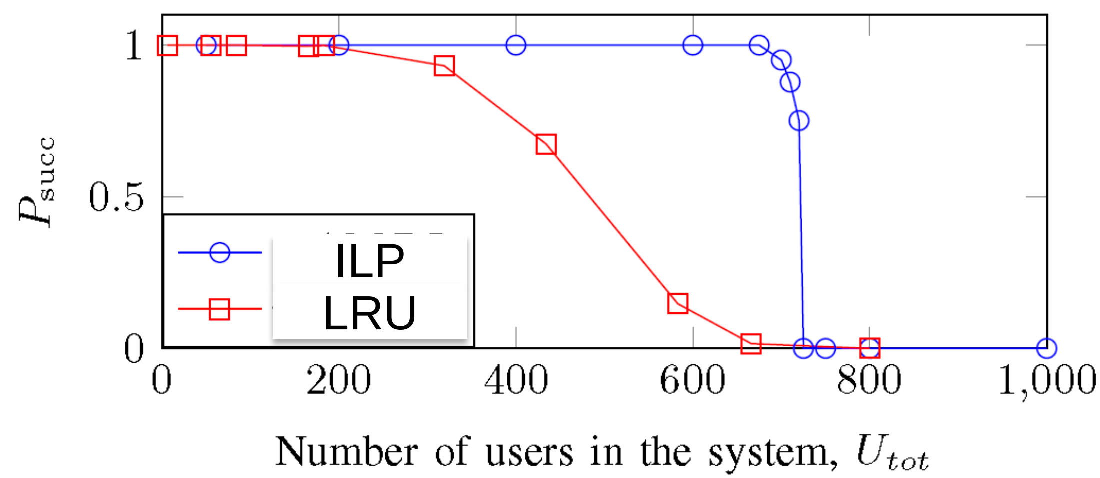
Results (II)

- We define the Contact Time Ratio, *CTR*, as the ratio between the longest and the shortest contact between the user and each Access Point.



- The success probability, P_{succ}, depends on *CTR* and on placement of caches.

- The success probability, P_{succ}, is represented versus the number of users in the system, U_{tot}. We compare the solution of our model using a proactive content placement, with the results obtained from simulations using a reactive policy.



Conclusion

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- A vehicular network can leverage the ICN framework to
  - simplify the delivery of contents
  - maximize the probability of obtaining the content.
- Increasing the storage capacity can be a cheap way to increase the success probability especially when APs are sparse.
- Storage at different levels of the tree topology also improves the performance in case of variable user speeds.
- Proactive deployment provides higher success probability against a reactive caching policy as LRU (but requires *a priori* knowledge).


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Thank you
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