# UMOBILE ACM ICN 2017 Tutorial

## Opportunistic wireless aspects in NDN

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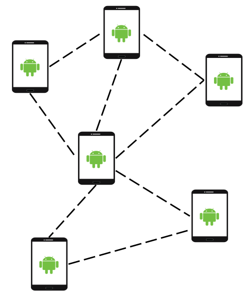
# Session Overview

1. **Opportunistic Networking in UMOBILE**
   - Wireless NDN: current picture
   - Extension of NDN Android to Opportunistic Networks (NDN-OPP)
2. **Handling Data: Opportunistic Forwarding**
   - Exploiting any communication opportunity
   - Social-aware opportunistic networking algorithm
3. **Handling Interests: Dissemination of Name Prefix Reachability**
   - Multi-path routing
   - Adaptive forwarding
4. **NDN-OPP presentation**
   - Experimental setup
   - Demo

# 1. Opportunistic Networking in UMOBILE

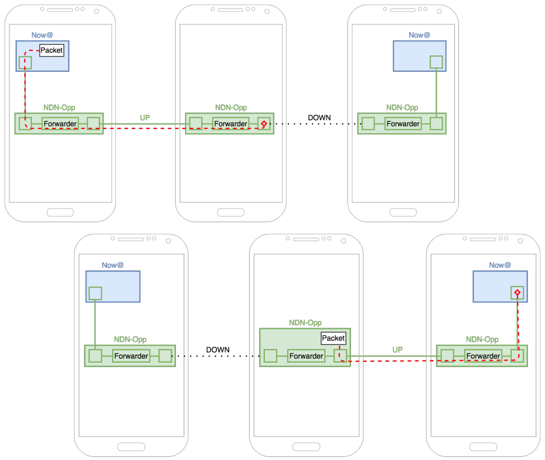
# UMOBILE

## Wireless NDN: Current Picture



### NDN for wireless networks

- Focused on MANET, where machines are not constrained devices.
- Focused on wireless sensor networks and sink-centric data traffic.
- HOWEVER, assumes communication paths between any pair of nodes at any moment in time.

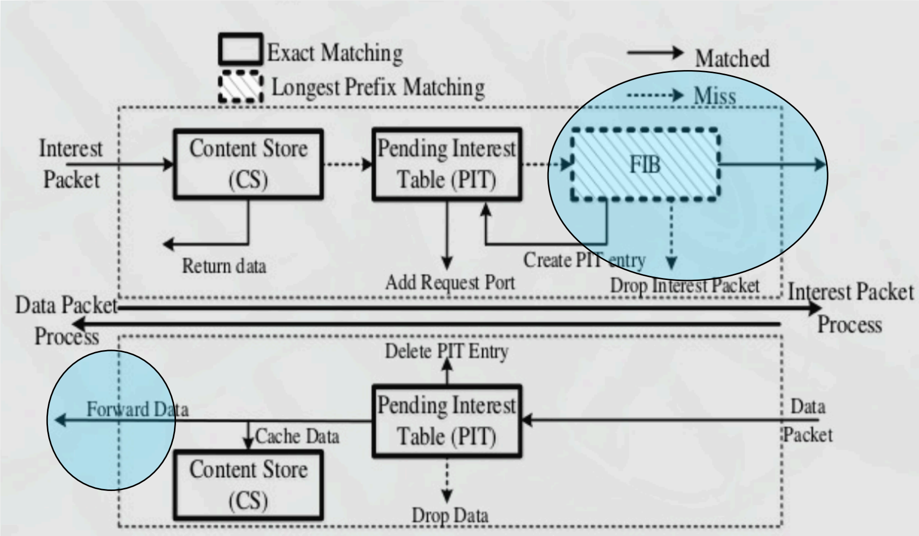



### NDN operation in opportunistic wireless networks

- No prior effort.
- Opportunistic wireless networks:
  - Do not assume communication paths between any pair of nodes at any moment in time.
  - Exploit any communication opportunity to forward data towards receivers.
- Motivation:
  - Driven by devices coming within transmission range: e.g. Wi-Fi direct and Bluetooth.
  - Handle intermittent transmission opportunities: interface with queuing system.
  - Novel approach to forwarding and routing.

# NDN for Opportunistic Networks

## Handling Interests and Data Transmissions




### *Handling Interests*

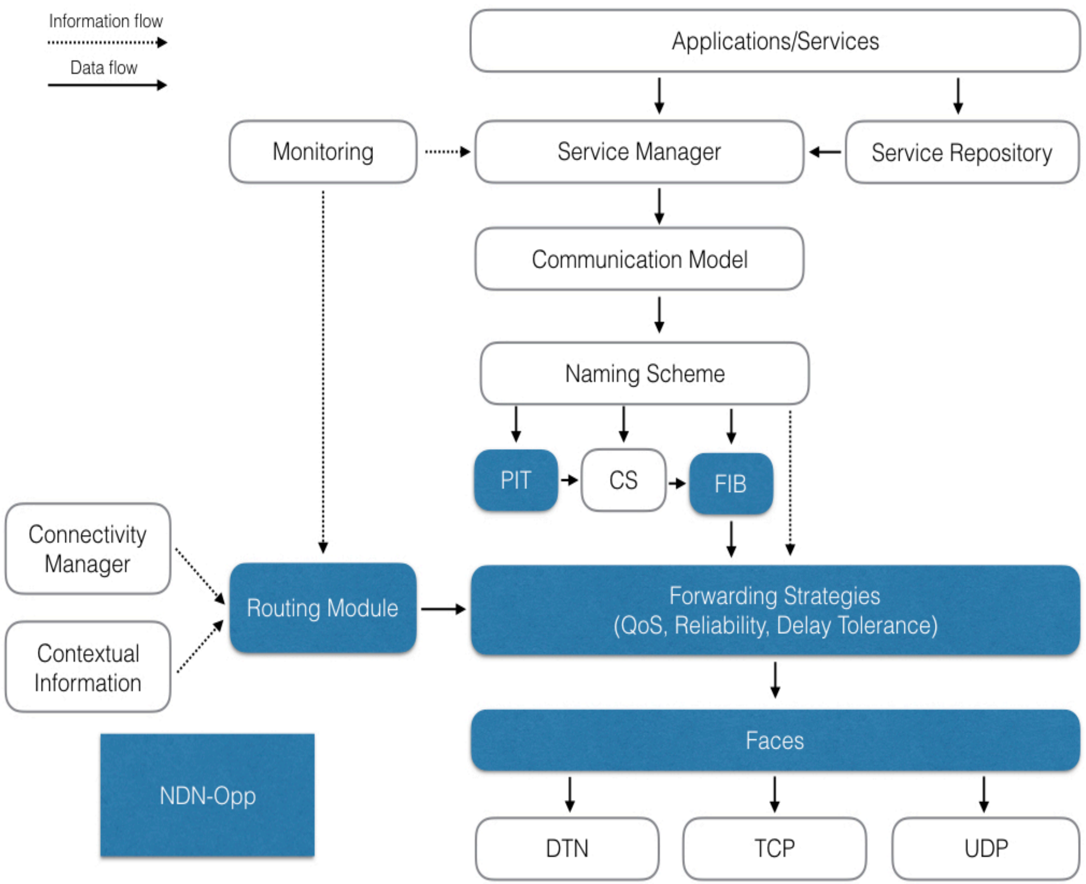
- Hypothesis A: Carrier
  - May lead to high latency.
- **Hypothesis B: Dissemination of Name Prefix Reachability**
  - Assumption: Data sources are subjected to lower intermittent connectivity with high probability.
  - Study: Multi-path routing combined with adaptive forwarding.
- Hypothesis C: Opportunistic Forwarding
  - Assumption: Data sources maybe subjected to high intermittent connectivity with high probability.
  - Study: Opportunistic forwarding strategy similar to the one used to handle data packets.

### *Handling Data*

- Hypothesis A: Breadcrumb approach as in NDN
  - May lead to network flooding in opportunistic networks.
- **Hypothesis B: Opportunistic Forwarding**
  - Selective forwarding strategy based on probability of neighbor to meet node interested in name prefix.
  - Requires:
    - Computation of social weights for each potential destination (interested node) of a name prefix.
    - Forward data if neighbor has higher probability to deliver to the data packet of a certain name prefix.

# NDN-OPP

## Updated NDN Modules & Set of Applications



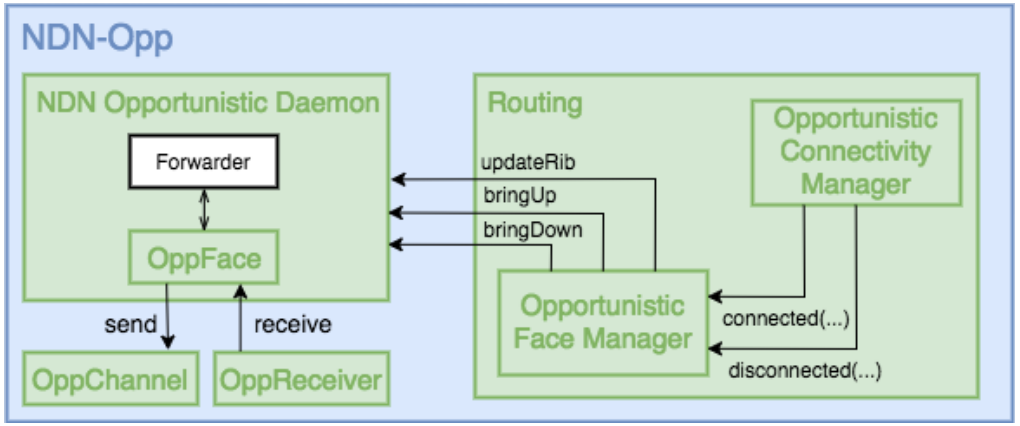

Oi! Short messages – Naming: /app/Oi!/Receiver/Source

Now@ Data Sharing – Naming: /app/now@/topic/sub-topic

### NDN-OPP as a NDN Android package

- Opportunistic Face (OppFace):
  - Support opportunistic communications
  - Current implementation for Wi-Fi direct
- Routing engine able of:
  - Compute routes toward sources based on metrics such as data reachability cost.
  - Compute proximity weights towards name prefixes based on metrics such as social proximity.
- Forwarding engine able of:
  - Forwarding data based on probability of meeting nodes interested in name prefixes.
  - Forwarding Interests via multiple next hops.
- Two new fields on the PIT:
  - SW = Social Weight towards this interest (1 = receiver)
  - TTL = time frame over which node interest is still valid

# NDN-OPP
## High-Level Specification




**Opportunistic Face (OppFace)** Demo

Implements a queuing system to cope with the intermittent nature of wireless links.

**Face Manager**

Maintains OppFaces of known peers.

**Opportunistic Channel and Opportunistic Receiver**

Logic for transmitting and receiving packets on the lower-level channel.

- Implementation A: TCP. Demo
- Implementation B: connectionless transfers based on service discovery.

**Connectivity Manager**

Maintains the low-level communication channels.

Includes support for push communication. Demo

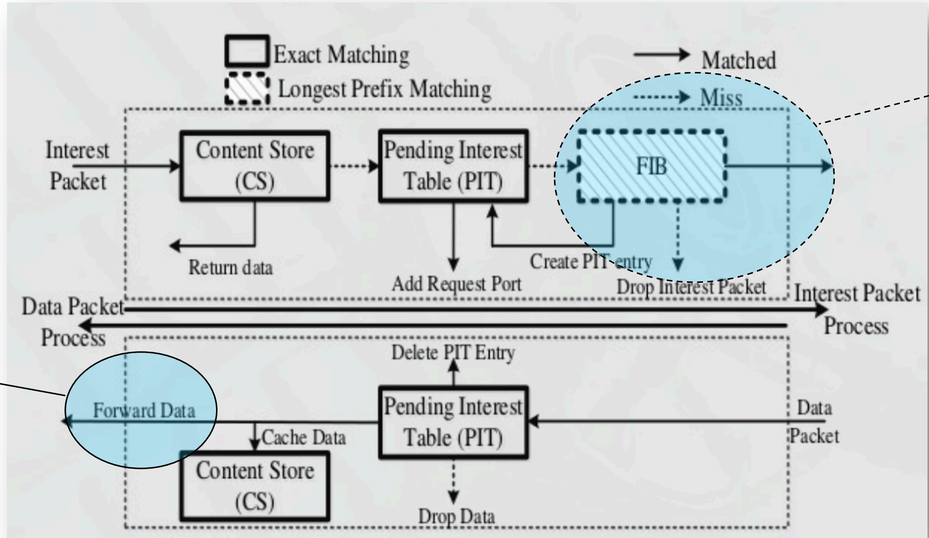
**Forwarder**

Performs forwarding based on different strategies.

**Router**

Computes next hops for Interest and Data packets based on a variety of indicators.

# 2. Handling Data: Opportunistic Forwarding




Interests Carried

**Selective Data Forwarding Strategy**

# NDN-OPP

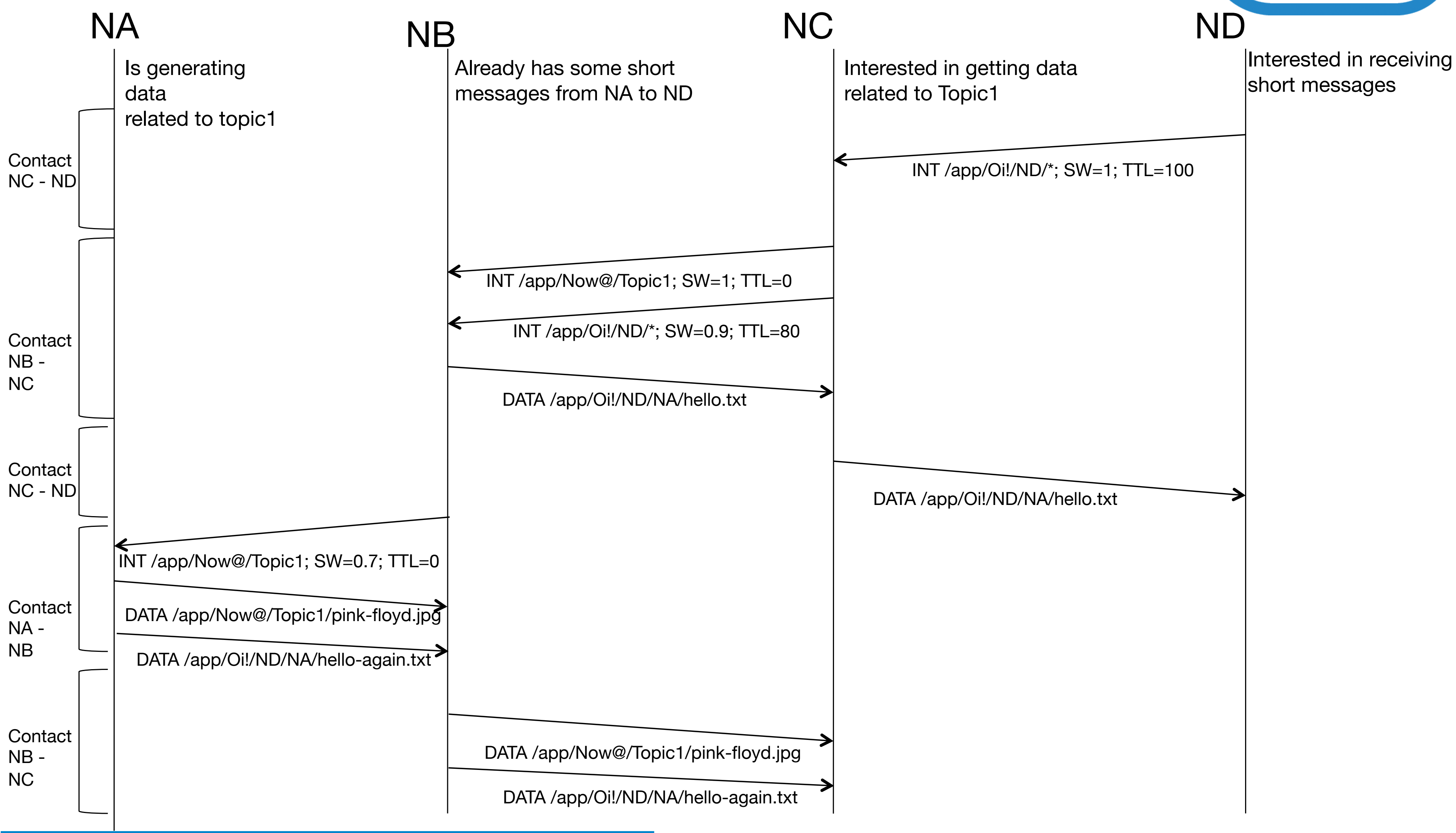
## Selective Data Forwarding Strategy

- Selective forwarding strategy based on probability of meetings nodes interested in some name prefixes.
  - Basic algorithm:
    - Node NX forwards data to a node NY
      - If Social Weight (SW) of NY towards the name prefix > SW of NX, in the current daily sample.
    - If NY has no SW towards the name prefix, NY may still get the data packet:
      - If and only if importance of NY > important of NX, in the current daily sample.
- Social weights:
  - Depends upon name prefix:
    - Oi! name prefix (/app/Oi!/*/Nb): SW = probability of meeting Nb
    - Now@ name prefix (/app/Now@/topic): SW = probability of meeting nodes interested on Topic.
  - Provided by:
    - Contextual Manager: SW of current node.
    - From PIT: SW of neighbor nodes.

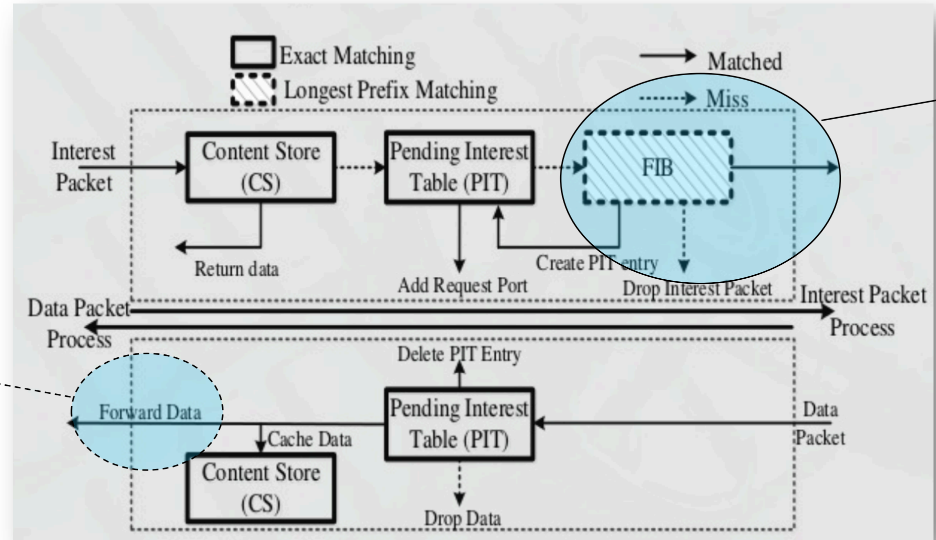
- Social-aware forwarding algorithm imported from Opportunistic Networking literature:
  - Waldir Moreira, Paulo Mendes, Susana Sargento, "Opportunistic Routing based on daily routines", in Proc. of IEEE WoWMoM workshop on autonomic and opportunistic communications, San Francisco, USA, June, 2012.
  - Waldir Moreira, Paulo Mendes, Susana Sargento, "Social-aware Opportunistic Routing Protocol based on User's Interactions and Interests", in Proc. of AdhocNets, Barcelona, Spain, October 2013.

# NDN-OPP

## Selective Data Forwarding Strategy: Example



# 3. Handling Interests: Dissemination of Name Prefix Reachability




Multi-path Routing with Adaptive Forwarding

Selective Data Forwarding Strategy

# NDN-OPP

## Multi-path Routing with Adaptive Forwarding

### Major Assumptions

- Data sources are subjected to lower intermittent connectivity with high probability.
- Any device that stores a data copy can announce its name prefix (long match).
- Link State Announcements (LSA) are exchanged based on Interest / Data messages.
- Packets are digitally signed based on an hierarchy reflecting the structure of the opportunistic networking domain.

### Major Requirements

- Does not build network topology, due to the dynamic nature of the opportunistic network.
  - Does not need to run Dijkstra to produce multiple next-hops for each destination node (name prefix source).
  - Multi next-hops for each name prefix are produced based on local information that encodes data reachability.

- Avoid sending periodic Hello messages among intermittent connected neighbor nodes.
  - Failure and recovery detection based on management of Opportunistic Faces.

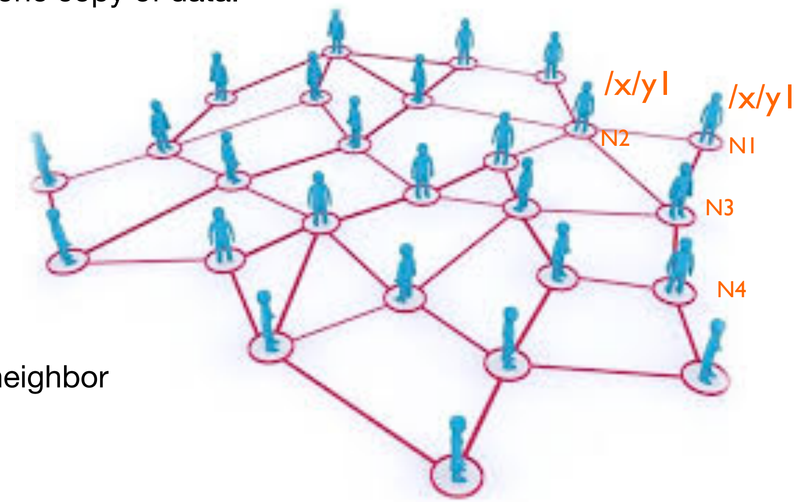
- Selective dissemination of LSA due to the dynamic affinity network of each node.
  - LSA are exchanged between (N-x) number of neighbours

# NDN-OPP

## Multi-path Routing based on Data Reachability

**List of next hops towards a name-prefix based on data reachability cost:**

- Metric dV: data validity set up by the data owner.
- Metric LC: link cost based on the average wireless contact duration via interface I.
- Rationale: Select interfaces with high probability to lead to at least one copy of data.




**LSA (/x/y1) in a node Nx:**

- Local copy: LSA = f (dV$_{Nx}$ (/x/y1))
- Otherwise: LSA = f (LC$_{NB}$ , LSA$_{NB}$ (/x/y1)), LC is a Link cost toward its neighbor

**Dissemination of LSA (/x/y1) by N3:**

- N4 recomputes LSA$_{N3}$ based on LC$_{N3}$
- N4 accepts LSA$_{N3}$ (/x/y1) if LSA$_{N3}$ - avrLocalLSA (/x/y1) > X to insure multi-path diversity
  - Increases the probability of delivering Interest packets.

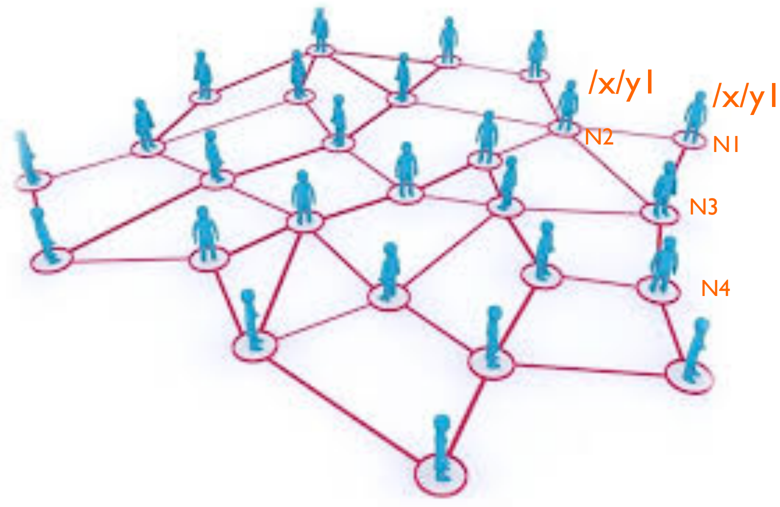
# NDN-OPP

## Adaptive Forwarding based on Interface Ranking

- Interface ranking based on metrics A, U and D:
  - A: neighbor degree centrality (Collected from Contextual Manager)
  - U: neighbor availability (Collected from Contextual Manager)
  - D: time lapse between forwarding Interest and getting date – indication of distance from nearest data copy
  - Rationale: Uses the interface that provides higher deliver probability or low delay (study item)

### Forwarding based on a set of interfaces I

- For each name prefix in the RIB a node:
  - Ranks the interfaces based on A, U and D
  - Forwards interest packets through the highest rank interfaces
- Ranking of Interfaces is updated based on:
  - New A and U provided by contextual manager
  - New D computed based on time lapse between Interest and Data.




### Rank$_I$ (/x/y1) in a node Nx:

- Increases with **A** and **U**
- Decreases with **D**
- **D** may have higher importance than **A** and **U** because:
  - **A** and **U** provide an indication of potential transmission success
  - **D** reflects transmission quality

# NDN-OPP Routing
## NSLR as Starting Point?

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### NLSR Used Functionalities:

- Hierarchical naming scheme.
- LSDB synchronization on top of Interest/Data packets.
- NDN embedded security.

### NLSR Functionalities not Used:

- LSA for adjacency (just LS – Link state).
- Multipath computation based on Dijkstra's algorithm.
- Hello protocol for neighbor failure and recovery detection.

### Named-data Link State Routing (NLSR)*

- Reuse a mature routing algorithm: link state
- NDN native
  - Names, not addresses (networks, routers, processes, data, keys)
  - Interest/Data are used to distribute routing info.
- Multipath support: modified Dijkstra's algorithm to produce a ranked list of next-hops for each name prefix.
- Security
  - a trust model for intra-domain routing
  - Routing data is signed by originating router and verified by receivers based on trust model.

* AKM M. Hoque, S. O. Amin, A. Alyyan, B. Zhang, L. Zhang, and L. Wang. *NLSR: Named-data link state routing protocol*. In ACM SIGCOMM ICN Workshop, 2013.

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### What do we do different to adapt NDN to Opportunistic networks?

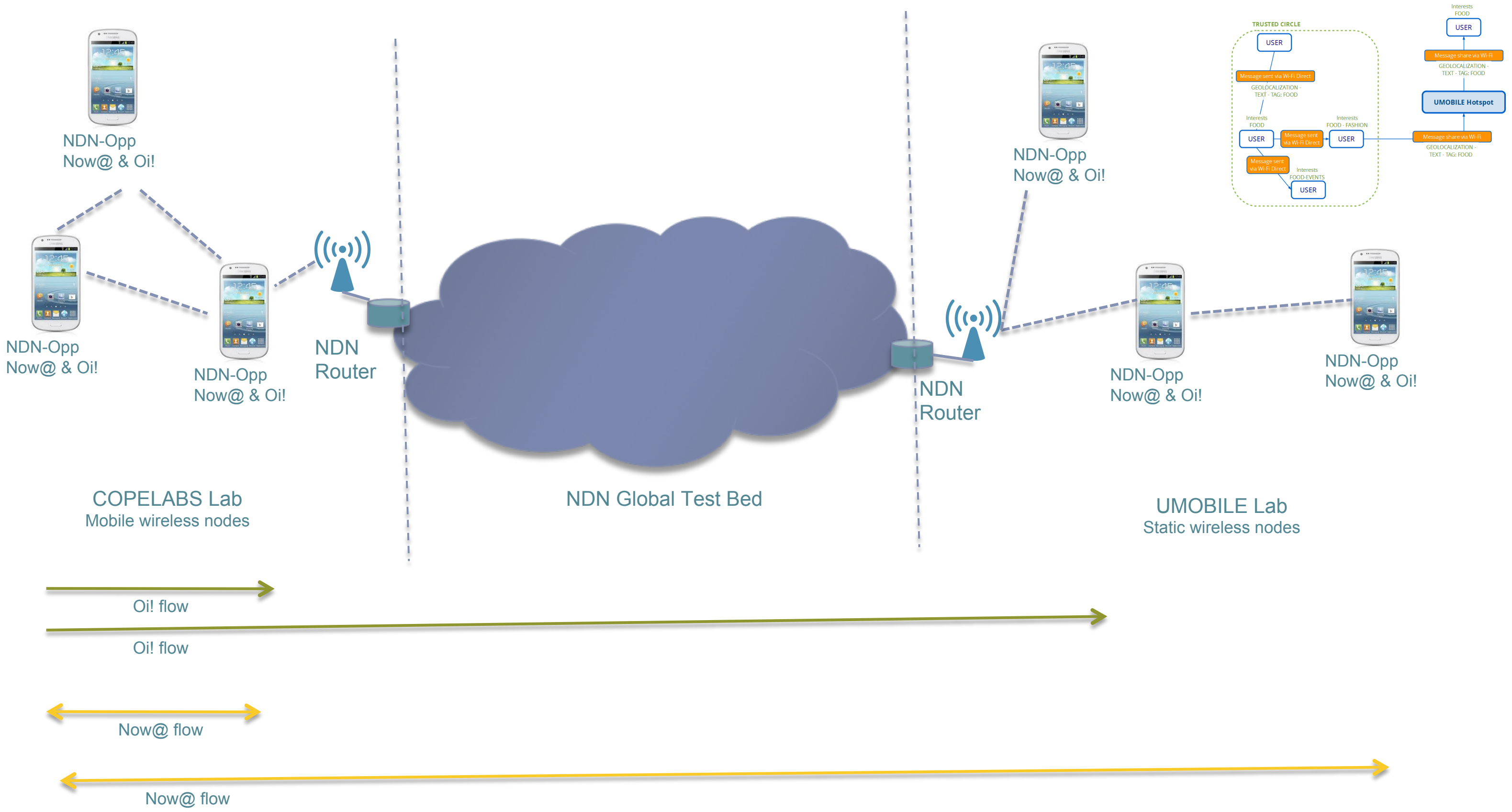
- Dissemination of LSAs of name prefixes.
- No dissemination of LSAs Adjacency.
- Selective dissemination.
- Any device that stores a data copy can announce its name prefix (long match).
- Link/Interface management based on Opportunistic Faces.
- LSA for name prefixes are deleted when dV expires.

# 4. NDN-OPP Demo

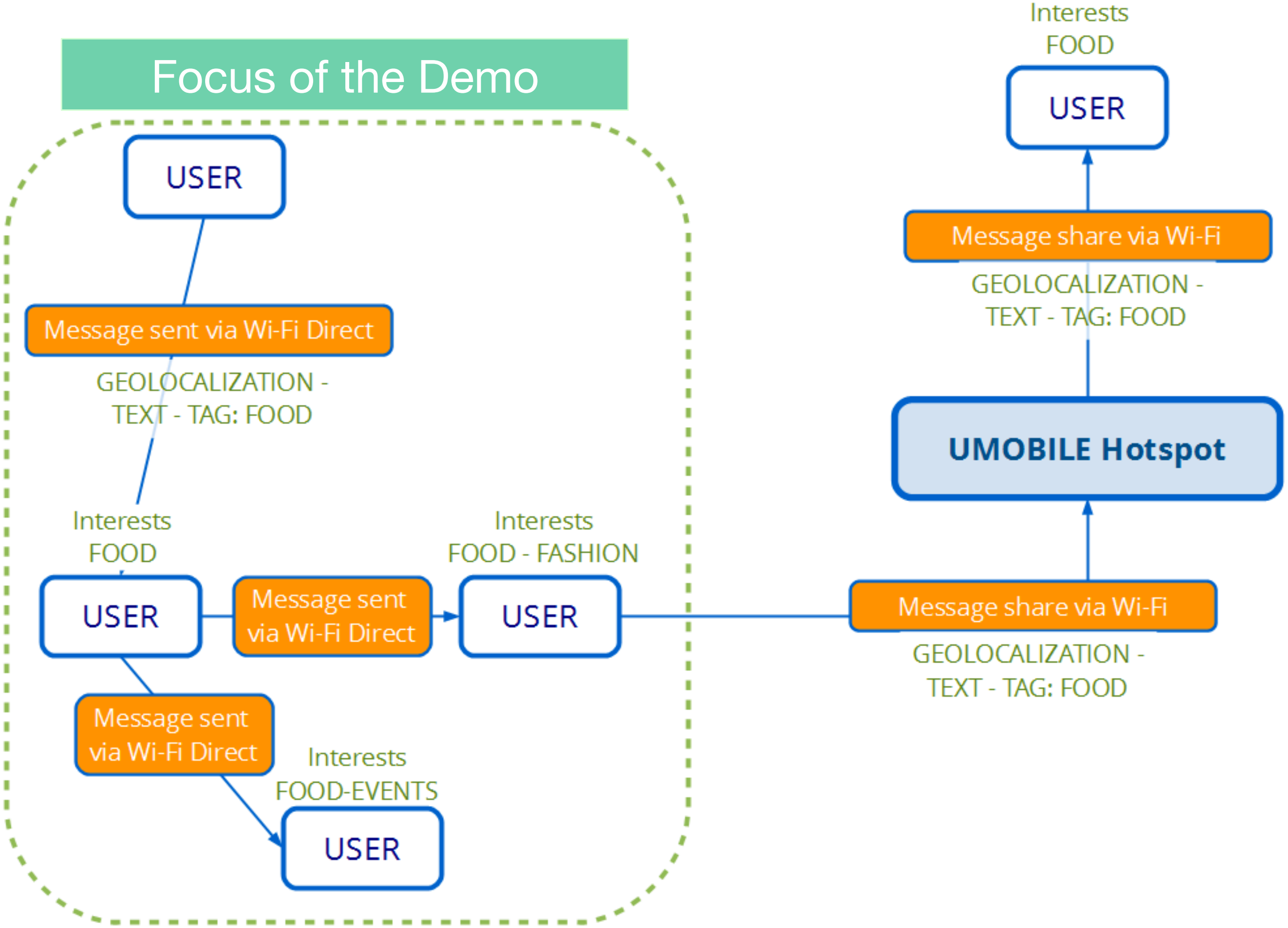
**NDN-OPP on GitHub:**
http://github.com/COPELABS-SITI/ndn-opp

# UMOBILE

## NDN-OPP experimental setting



# UMOBILE
## Social-Routine scenario Proof-of-Concept



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