

制約付きInterest転送機能を有する 参加型クラウドセンシング プラットフォーム ： 網外知見の収集法

アシシュ マン シング プラダン

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Abstract

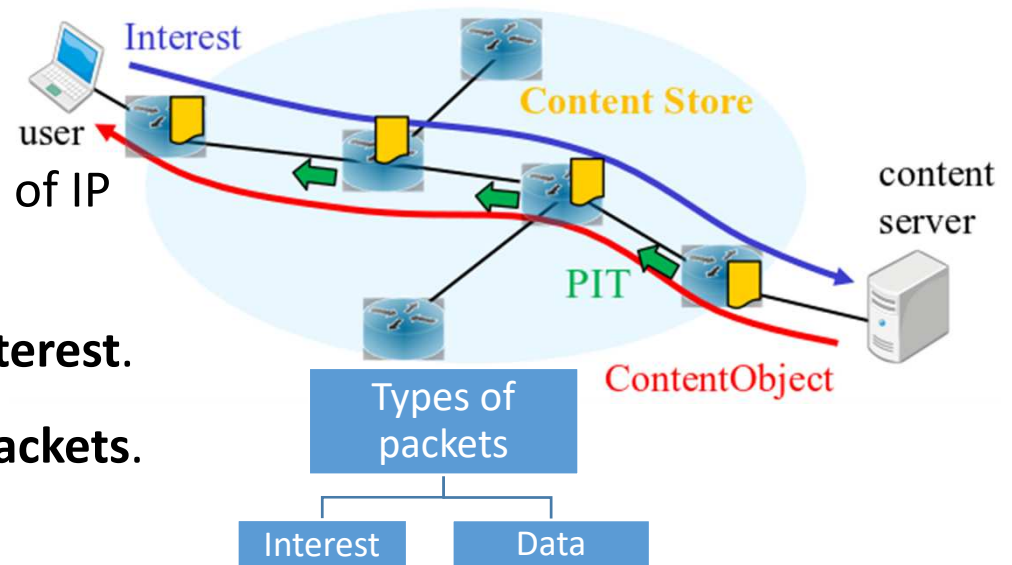
- 本研究では、Named Data Networking (NDN) 機構を用いて、情報収集者が、ネットワーク外部の特定エリアに滞在するユーザ集合や特定の属性を有するユーザ集合から、限定的にオピニオンや知見などの網内データベースには存在しないデータを獲得するためのプラットフォーム構築法を提案する。
- 従来のナイーブなNDNやクラウドセンシングのアプローチとは異なり、エリア・属性ベースフィルタリング機能、遅延耐性機能の導入により、NDNのInterest転送経路上にない、いわゆる「外部ネットワーク」の位置からデータが収集される点が従来にない特徴である。

Contents

- Named Data Networking(NDN)
- Mobile Crowdsensing(MCS)
- Motivation and Goal
- Related Works
- Proposed Model
- Evaluation
- Discussion
- Conclusion

Introduction – Named Data Network(NDN)

- New Internet architecture.
- **Routing based on data names** instead of IP address.
- Consumer sends request as **named Interest**.
- Provider provides answer with **Data packets**.



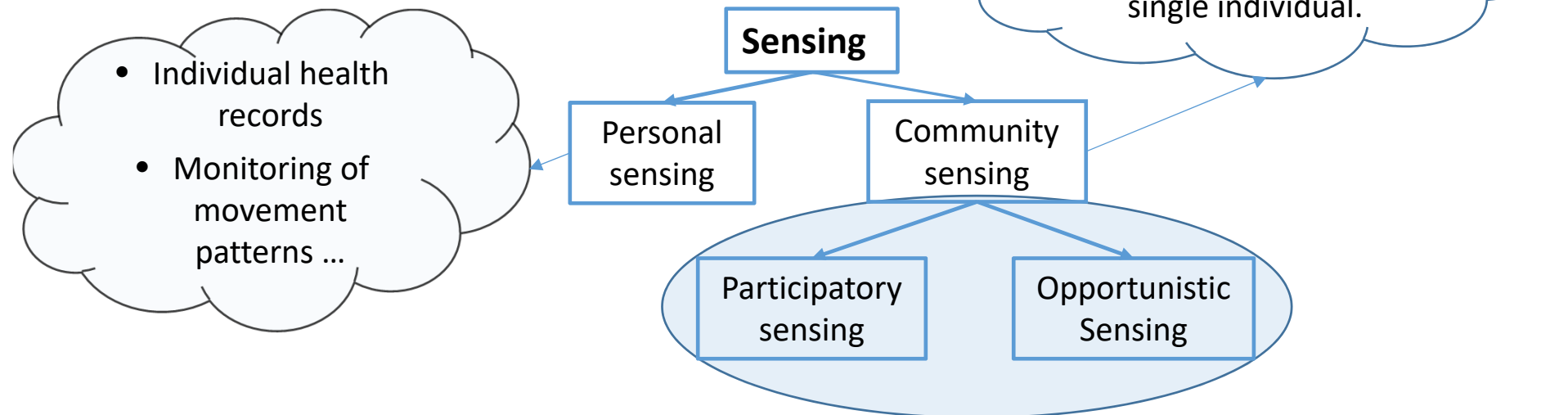
Routers maintain **three data structures**

- **FIB(Forwarding Information Base)**
 - Name-based routing table (to search for the data provider)
- **PIT(Pending Interest Table)**
 - Table with entries of incoming interests (removed when data is received)
- **CS(Content Store)**
 - Storage for forwarded data (used if same data is asked again)

Introduction - Mobile Crowdsensing(MCS)

Individuals with sensing and computing devices **collectively share data** and extract information to measure and map phenomena of common interest.

Where does MCS lie in the classification of sensing?



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Motivation

Requirement for MCS:

- Collecting Data(Content)
- Sharing Data
- In summary, it is related to receiving and sharing information

Features of NDN:

- Content-oriented application and service
- Focus on the content of data rather than its location

Both of them are concerned with the content/information



So, using NDN architecture for MCS is very reasonable

Goal

- To implement crowdsensing using NDN
- Design Interest flow suitable for crowdsensing
- Work on Area-focused Interest forwarding
- Significantly reduce the number of Interest Exchanges
- Reduce Data redundancy

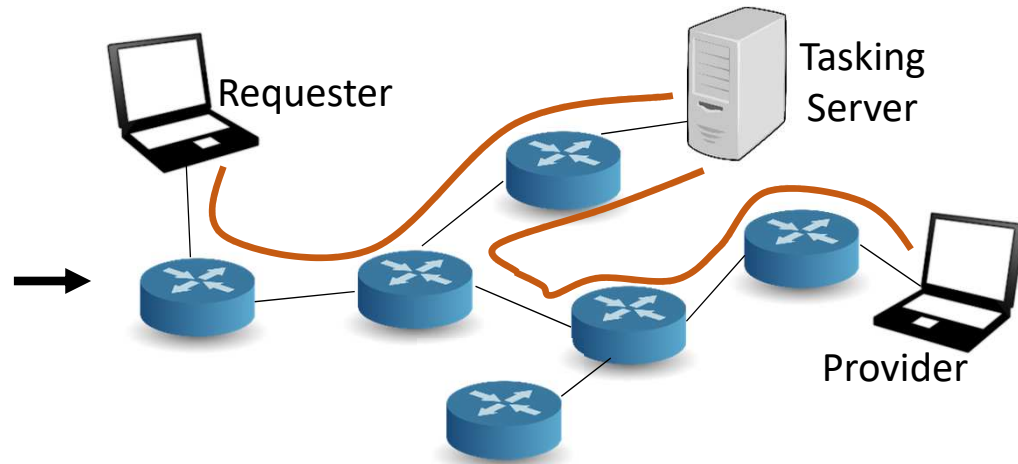
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Related Works

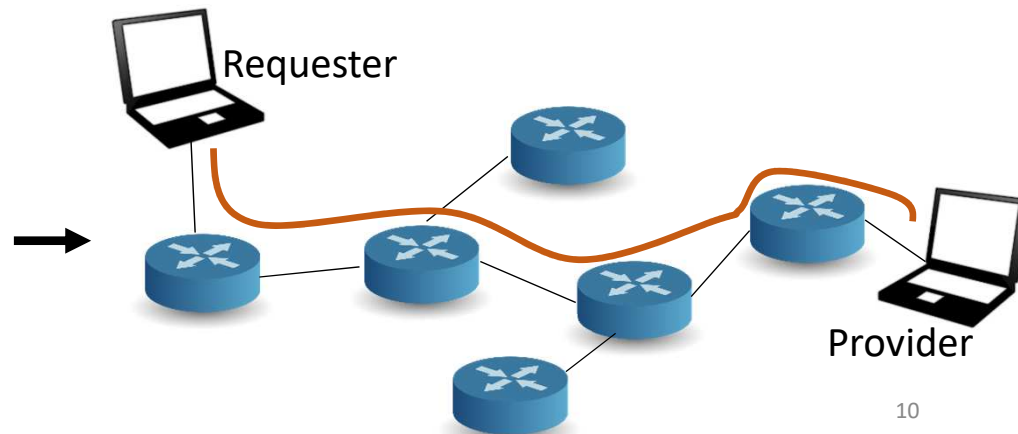
Current MCS Scenario:

- Aim for instant responses (e.g. emergency response, real-time traffic management)
- Implemented on **IP address**
- Tasking server **required**
- **Inefficient** interest distribution



Our proposed models for MCS:

- Aim for non-instant responses (e.g. local knowledge gathering)
- Based on **NDN architecture**
- Tasking server **not required**
- **Efficient** Interest distribution

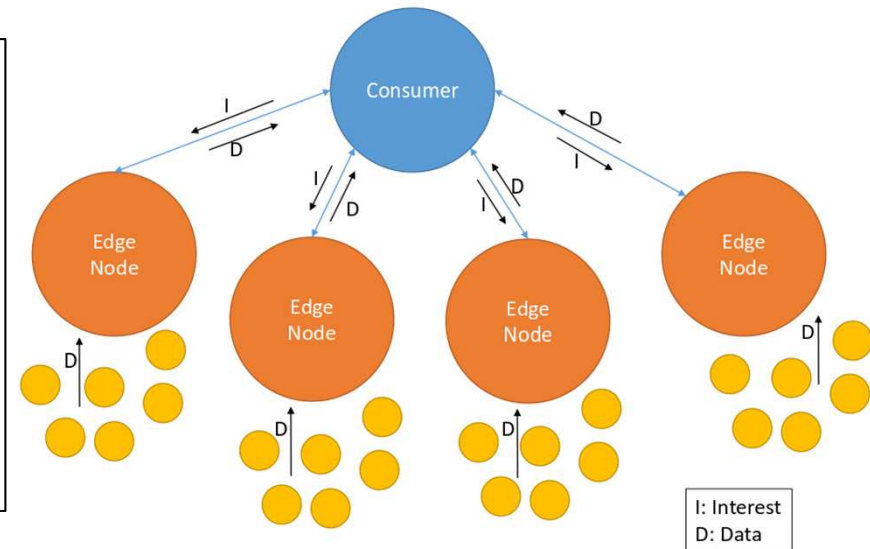


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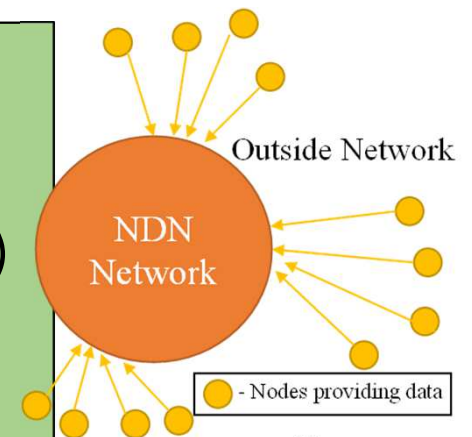
Proposed Model for MCS

1. The **consumer** generates the Interest
2. Interests reach the **Edge nodes**(Edge of NDN network)
3. The Edge nodes start collecting data from **mobile users**(**Outer** locations of NDN network)



Important points

- Mobile users are the actual producers.
- Work for the Edge nodes:
 1. Take the data from mobile users (Outside NDN network)
 2. Then forward it to the consumer (Inside NDN network)
- Thus, Edge nodes = Potential producer



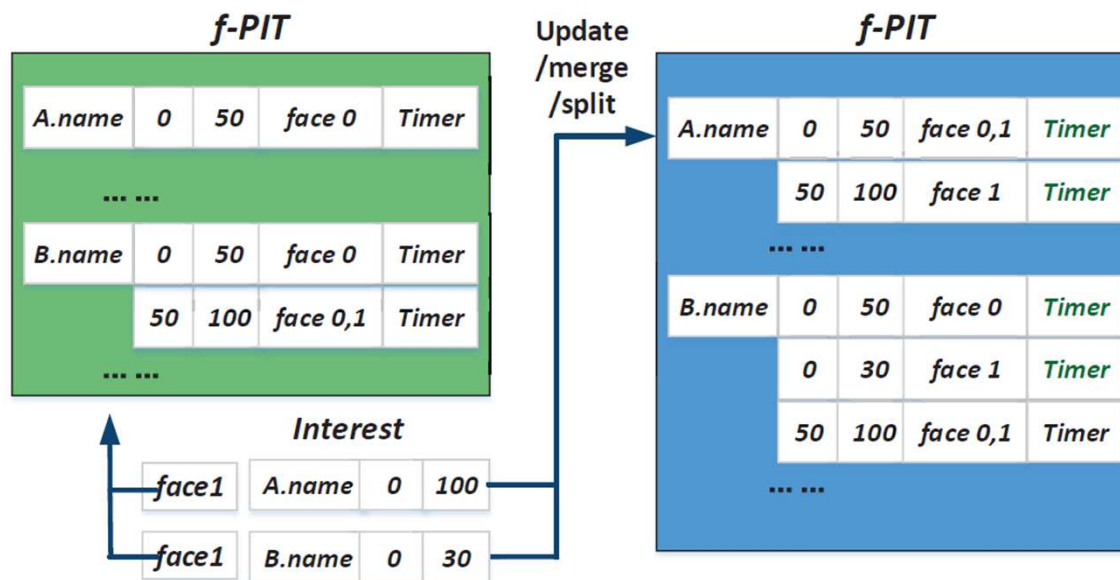
Proposed Model - Challenges

- PIT behavior manipulation to achieve Mobile Crowdsensing
- Area-Focused Interest Forwarding to send interests to selective areas
- Data collection termination to control the amount of data responses

PIT Behavior Manipulation

Typical NDN Mechanism

- One Interest packet should retrieve one Data packet.
- Useful when dealing with mobility, multipath forwarding, path failure etc.
- Can cause overload problems due to countless Interest Packet for same content object.



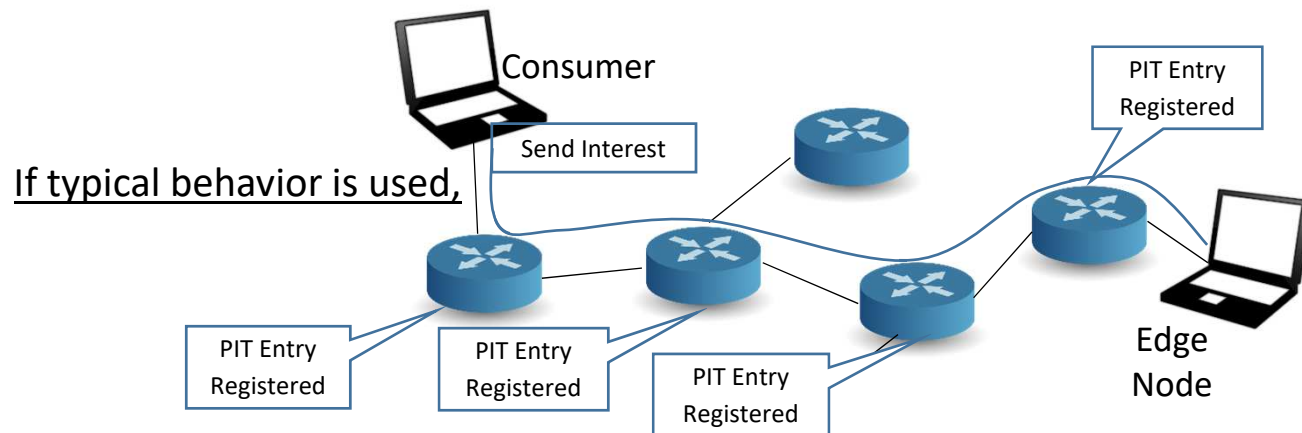
One of the related works:

- Flow-based NDN Architecture
- Core idea of Packing interest
- Successive chunks merged into one flow interest pkt

PIT Behavior Manipulation

Why is it required?

- To Send Just one Interest
- And Receive multiple data corresponding to the same Interest.



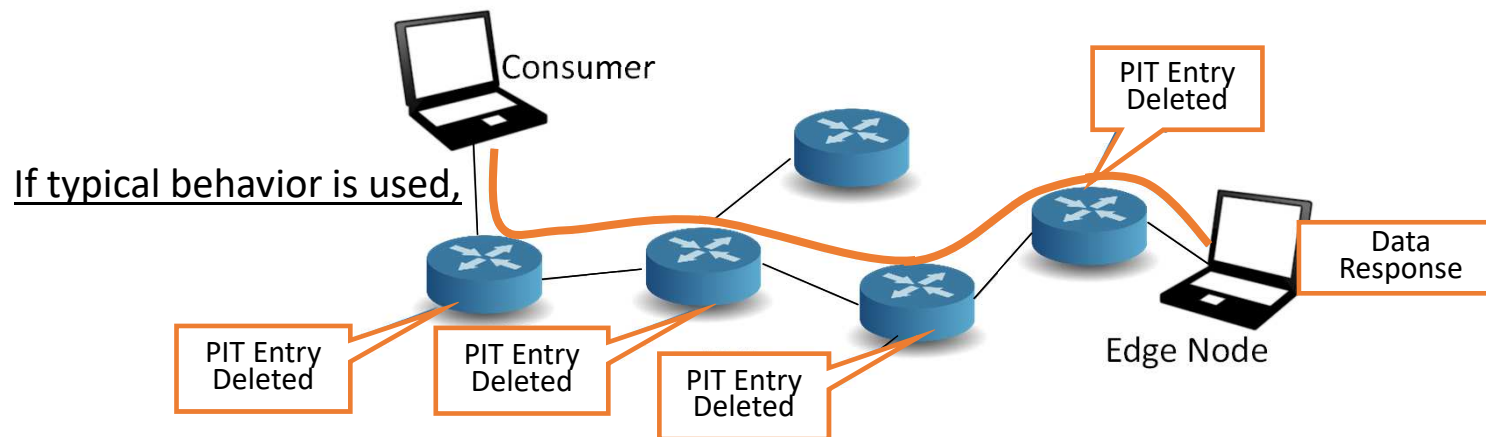
Proposed Solution:

- Change the PIT behavior
- i.e. Do not delete the PIT entry after forwarding the Data

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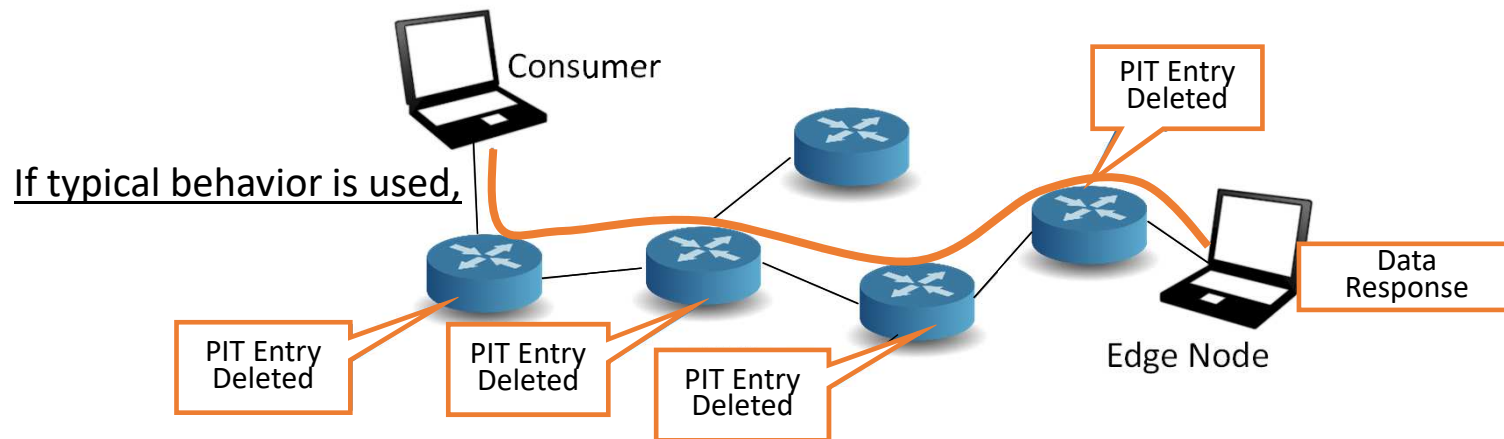
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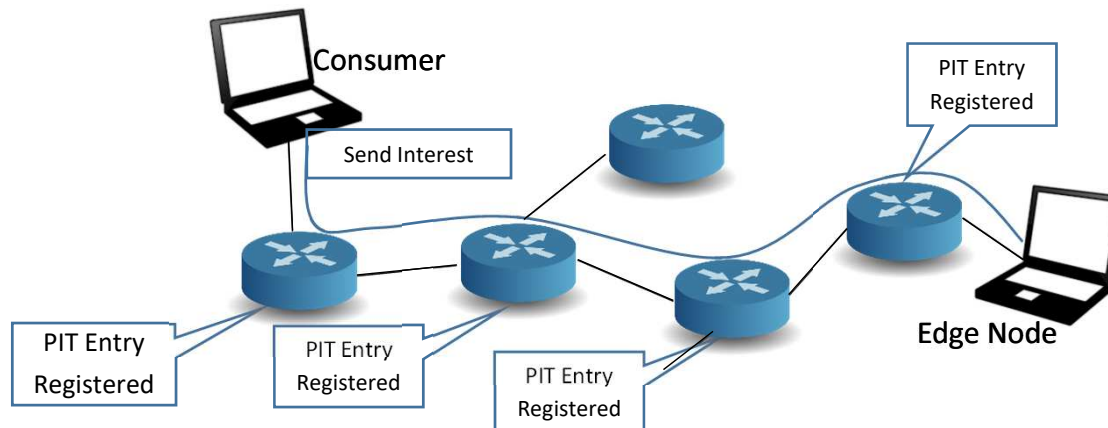
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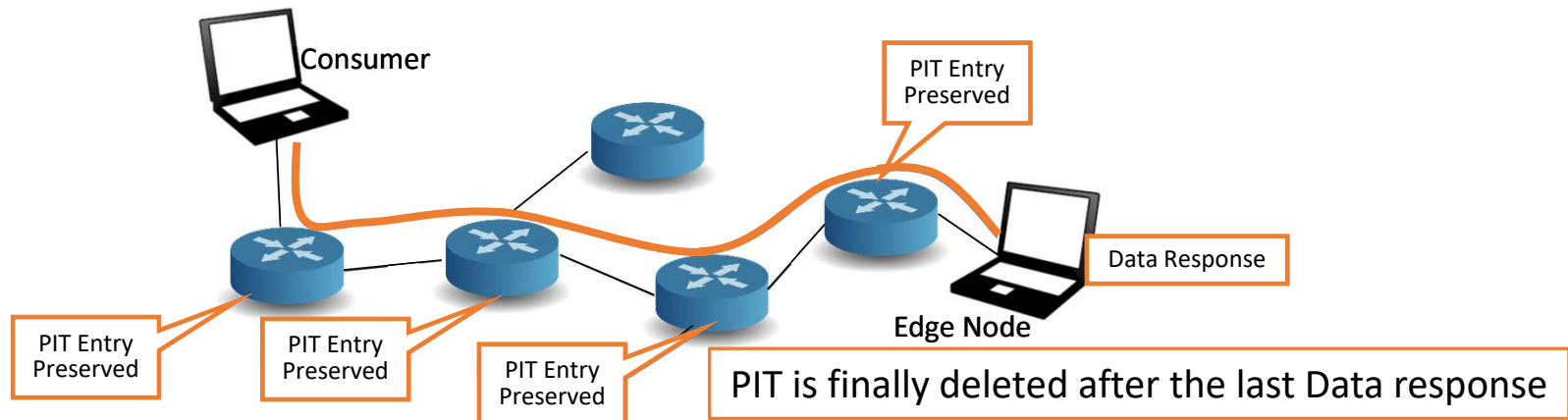
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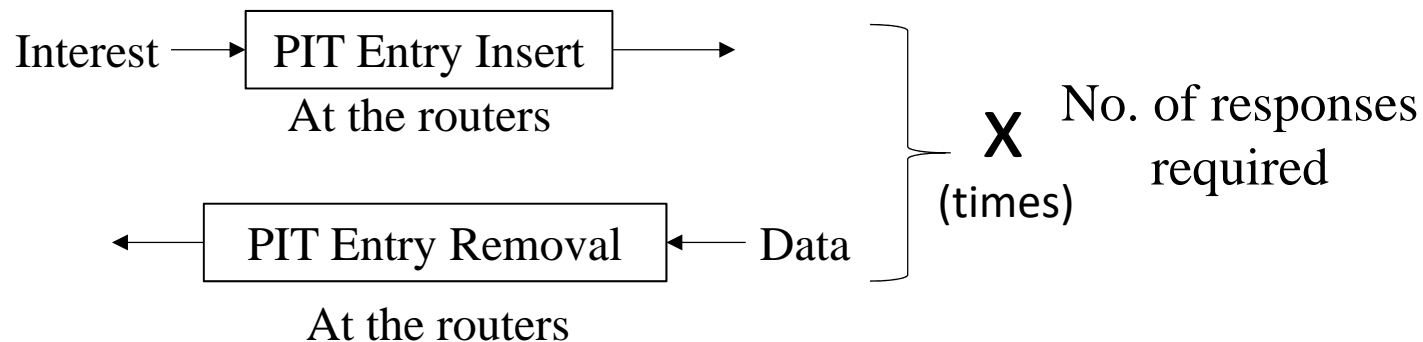
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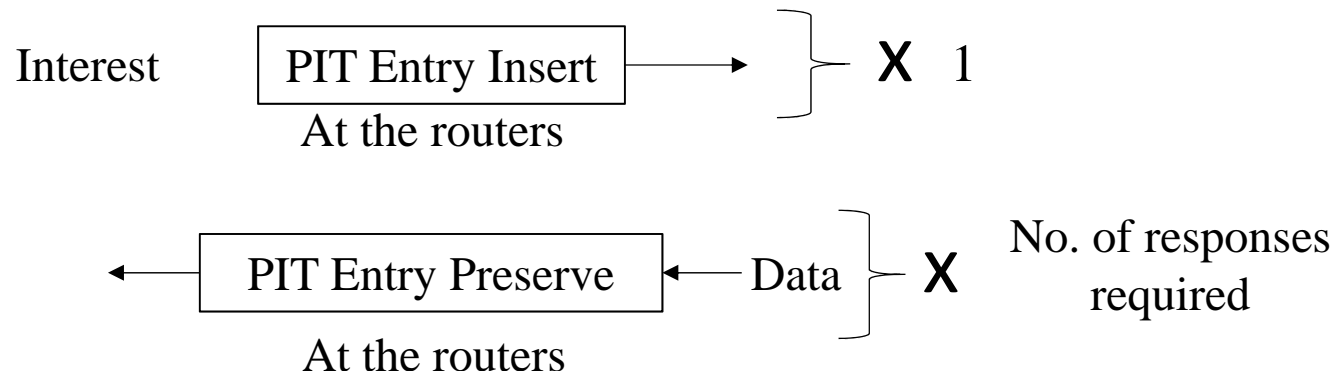


PIT Behavior Manipulation: Summary

Typical PIT working leads to same no. of Interests as Data responses



Altered PIT working leads to one Interests to retrieve multiple Data responses



Proposed Model - Challenges

- PIT behavior manipulation to achieve Mobile Crowdsensing
- Area-Focused Interest Forwarding to send Interests to selective areas
- Data collection termination to control the amount of Data responses

Area-Focused Interest Forwarding

Why is it required?

- To Send the interest to a selective number of producers.

Proposed Solution:

In NDN, the Producer can register some Data names in the FIB of the routers. All the Interests corresponding to this name are directed to that producer.

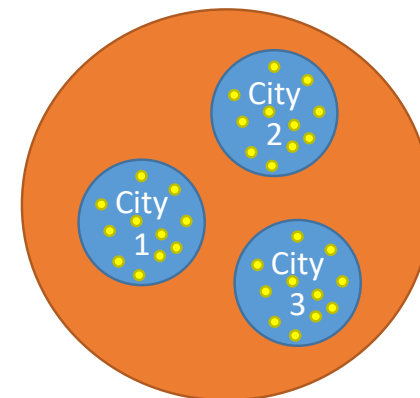
- Use the naming scheme(Data names) strategically so as to have some aspects of area in it.
- i.e. Decide the prefix appropriately according to the area.

Proposed Naming Scheme:

- /MobileCrowdsensing/<Area>/<TypeOfData>

Appropriate prefix:

- /MobileCrowdsensing/City1/Weather



Proposed Model - Challenges

- PIT behavior manipulation to achieve Mobile Crowdsensing
- Area-Focused Interest Forwarding to send Interests to selective areas
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Data Collection Termination

Why is required?

- The PIT behavior was changed
- So, the amount of data responses should be controlled

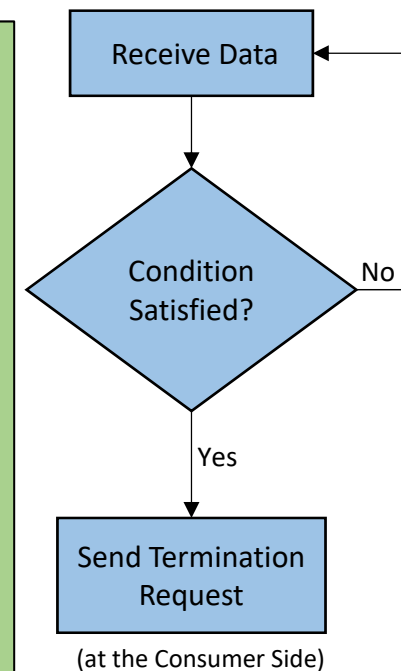
Proposed Solution 1: Consumer initiated termination

Proposed Solution 2: Edge node initiated termination

Data Collection Termination

Proposed Solution 1: Consumer initiated termination

- **At the consumer** end, check for the conditions to terminate.
- The termination conditions:
 - Number of data collected or
 - Some point at which the consumer gets satisfied
- After the termination conditions are satisfied, termination command is required to be sent
- Naming scheme:
/MobileCrowdsensing/<Area>/<TypeOfData>



Data Collection Termination

Why is required?

- The PIT behavior was changed
- So, the amount of data responses should be controlled

Proposed Solution 1: Consumer initiated termination

Proposed Solution 2: Edge node initiated termination

Data Collection Termination

Proposed Solution 2: Edge Node initiated termination

- By including the termination conditions in the Interest name when asking for the content
- This leads to formation of **various naming schemes** as desired by the consumer
- No termination commands required from the consumer side
- Puts the computation load on the edge side of the network

Possible naming schemes

Naming scheme 1:

/MobileCrowdsensing/<Area>/<TypeOfData>/<ResponsesRequired>

Naming scheme 2:

/MobileCrowdsensing/<Area>/<TypeOfData>/<Time>

Naming scheme 3:

/MobileCrowdsensing/<Area>/<TypeOfData>/<ResponsesRequired>/<Time>

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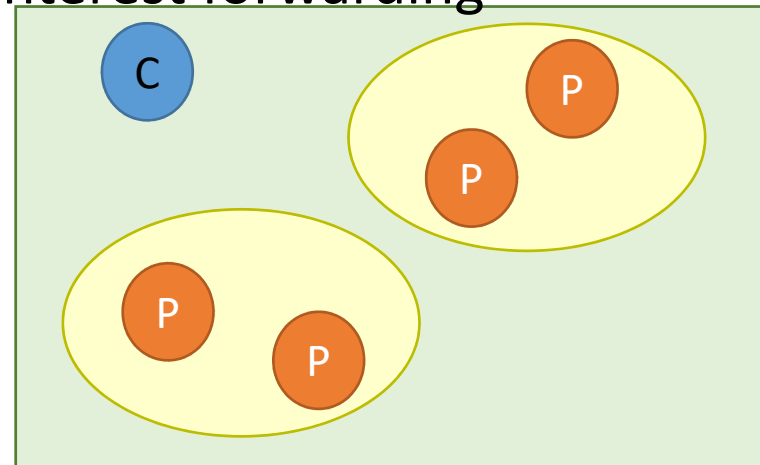
Evaluation

- **Simulation setting(ndnSIM):**

- 3X3 Node structure
- 1 Consumer
- 2 Distinct Areas
- 4 Potential Producers(2 in each area)
- Consumer initiated termination implemented

- **Evaluate:**

- Effectiveness of area-focused Interest forwarding
- Interest messages exchanged



Evaluation

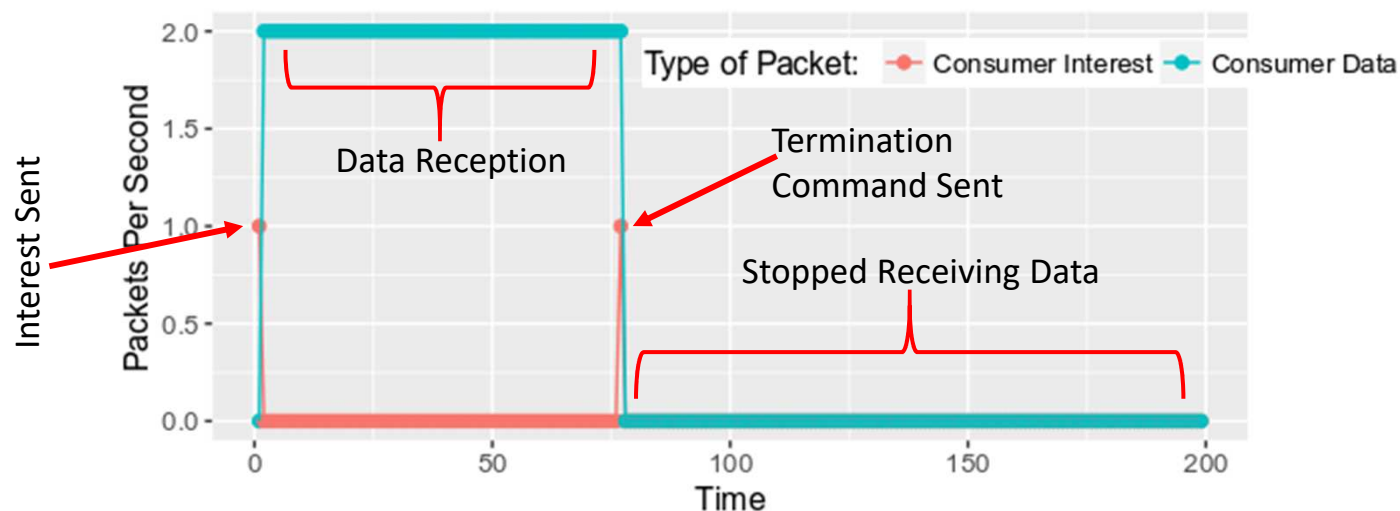
Effectiveness of area-focused Interest forwarding

1. The Interest from the consumer was aimed at one of the two distinct areas.
2. Simulation showed that the consumer received no data responses from the unwanted area.
3. As compared to the designed model, the naïve model has increased number of redundant responses as the number of areas is increased.

Evaluation

Interest messages exchanged

- The designed model has no more than 2 Interests forwarded from the consumer:
 1. The Interest message for the potential producers to start data collection.
 2. Termination request for data collection.
- As compared to the naïve model, Interest message for each data response is required.
- Thus message overheads are drastically reduced



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Discussion:

Importance of Reducing Redundancy

- Redundancy – One of the unwanted characteristic.
- Significantly reduces the effectiveness of the MCS system.
- As data collection has a cost associated with it, increase in redundancy will increase the cost

Redundancy can have different meanings:

- Generally, redundancy is created with same valued content.
- In our implementation, redundancy is created when responses are collected from unwanted areas
- There is also redundancy in the Interest sent as well.

Discussion: Importance of Reducing Redundancy

Mathematical Explanation of Redundancy

Result of Conventional Operation,

$$M_e = nI + (n-m)R + mR_{\text{red}} = \overbrace{2I + (n-m)R}^{\text{Essential Part}} + \underbrace{(n-2)I + mR_{\text{red}}}_{\text{Redundant Part}}$$

- $R_{\text{red}(A)}$ Increases as the no. of interest area increases.
- The $R_{\text{red}(PP)}$ also increases with increase in interest area.

Result of Proposed Operation,

$$M_e = 2I + (n-m)R + R_{\text{red}}, \quad R_{\text{red}(A)} = 0$$

- $R_{\text{red}(A)}$ is zero even though the interest area increases.
- The $R_{\text{red}(PP)}$ can still be present but remain constant.

Interest Redundancy, $(I_{\text{red}}) = (n-2)I$

Response Redundancy, $(R_{\text{red}}) = R_{\text{red}(A)} + R_{\text{red}(PP)}$

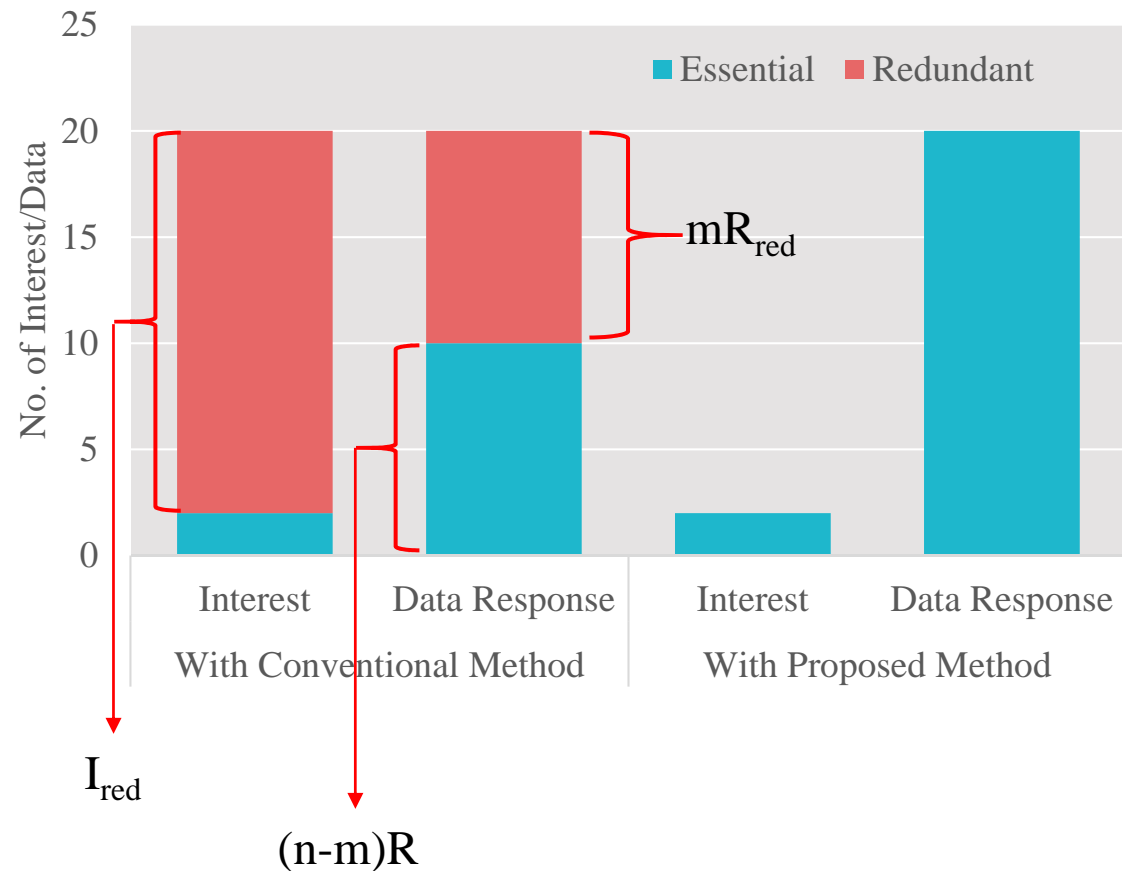
Response from Redundant Area

Response from Redundant Potential
Producer

Discussion: Importance of Reducing Redundancy

Consider,

- Two different area
 - One interest area
 - Redundant area
- Equal number of Potential producers
- Consumer wants 20 responses ($n=20$).
- $R_{red} = R_{red(A)} + R_{red(PP)}$



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Conclusion

Summary:

- The redundant data responses can be drastically reduced through area-focused Interest forwarding.
- By manipulating the typical working of the PIT, it is also possible to limit the Interest messages.

Future Works:

- Reduce response from redundant Potential Producer ($R_{\text{red(PP)}}$)
- Implement 'partial area filtering'.
- The mobile user's model can be improved to match a more practical environment.
- Use a bigger and practical topology.