# Maximum Information Coverage in Named Data Vehicular Cyber-Physical Systems

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***Abstract*—During the past two decades, we have witnessed a tremendous development in Vehicular networks, while exploring emerging communication technologies such as vehicular cyber-physical systems (VCPS). Basically, VCPS requires multimodal data from the physical system to take appropriate decision and actions, for example, the congestion warnings, applying brakes, adjusting speed limits, etc. However, there are multiple systems interconnected in the VCPS with different communication capabilities and data communication between those systems that lead us to a challenging task. In this paper, we consider named data networking (NDN) as a promising solution to enhance the reachability of Data among multi-hop VCPS. NDN offers a simple pull-based content communication in the network with multiple interfaces and also supports heterogeneity in terms of communications technologies. The proposed NDN forwarding scheme enables vehicles to send one Interest (request) to collect multiple instances of the Data from different content sources in the network. Simulation results show that the proposed scheme can collect information from many nodes that are at longer distance from the information requesting nodes.**

***Index Terms*—NDN, VCPS, Multimodal Data, Information Coverage.**

## I. Introduction

In typical vehicular applications, such as the forward collision avoidance, managing traffic congestion information, dynamically adjusting the speed limits, etc., require a real-time information (*communication*) between the vehicles and traffic management centers (*physical systems*). Based on this information, the vehicles can take special actions (*control*), such as the vehicles may reduce speed by applying brakes and take alternate routes, speed limits on highways and the traffic signal duration may be adjusted dynamically by the traffic control center, and so forth. This integration of the cyber and physical vehicular system is termed as the vehicular cyber physical system (VCPS) [1]–[4].

VCPS is generally defined as "a well-engineered synergy between the cyber and the physical vehicular worlds through communication technologies to form a unified and intelligent transportation system". The VCPS related applications require timely information from multiple vehicular network elements, such as; RSUs, traffic light sensors, vehicles, sensors installed on or at the road-side, etc., to make intelligent decisions. Hence, a reliable and an efficient multi-point communication architecture is necessary to realize the efficient VCPS.

Meanwhile, a Future Internet architecture called named data networks (NDN) [5] is being explored for vehicular networks [6], [7] that deals Data as a first class citizen of the network entity. NDN is the implementation variant of its forebearer architecture called content-centric networking (CCN) [8], which is one of the information-centric networking (ICN) architectures [9]. In addition to the name based content communication, NDN intrinsically secures the content in place of the communication channel and exploits the in-network caching. It adopts a simplified pull-based communication process, mainly involving two messages, *interest* and *data*. The consumer or a content seeking vehicle initiates the Interest message and a vehicle with the matching data or content (called *Provider*) replies with the Data message. Here, the content name is the common information in both Interest and Data messages. Also, the Interest message carries additional information including *NONCE* and content *Selectors*. This NONCE value is used to differentiate between different Interests requesting the same content. Commonly, for each content or chunk of the content, a separate Interest is generated by the consumer.

NDN maintains three data structures at each node to efficiently forward Interest and Data messages. Those data structures are pending interest table (PIT), forwarding information base (FIB), and content store (CS). The PIT structure is implemented to keep the state of the incoming Interest message's *Name*, *NONCE*, and Interface from which the Interest was received (called *inFace*). This *inFace* is also used to forward Data message that is received in response to the Interest with the matching *Name* entry in the PIT. On the other hand, the FIB consists of Name prefixes and the outgoing interfaces (*outFace*) where the Interest should be forwarded once the matching *Name* is found in the FIB. The complete or partial content received in the Data messages are cached in the CS to satisfy the future Interest requesting the similar content.

There are several schemes that have been proposed for NDN-based vehicular networks with an objective to retrieve specific information from any provider in the network [10]–[15]. However, in case of multiple providers, the information from a single provider is accepted and rest of the copies of that information could not be forwarded in the network. Such schemes are not suitable for VCPS because, in VCPS, a vehicle or any vehicular network component requires multimodal information[1] from multiple sources within its certain proximity to make an intelligent decision depending upon the application. However, in a typical vehicular NDN, the instance of an Interest is removed from the PIT once it receives the first Data message and rest of the Data messages are dropped. In this paper, therefore, we propose the named data retrieval algorithm to received multiple resolution data from different providers as a reply to single Interest message. The Interest message contains the name denoting the large resolution information form all the vehicles within the specified proximity of the consumer. To mitigate the Data storm from multiple sources, the proposed scheme uses the holding timer to avoid the Data collision at downstream nodes. The key contributions of this paper are four folded:

- Based on our knowledge, the proposed scheme is the first attempt to adopt NDN for discovering multimodal information for VCPS.
- The proposed scheme extends the concept of one interest one data to one interest multimodal content from different content sources or producers to increase the information coverage.
- The proposed scheme does not maintain any additional information in FIB structure of NDN.
- Proposed scheme can easily be extended to any application offered by the NDN for VCPS.

Rest of the paper is organized as follows. In Section II, introduction to NDN architecture and it's working principle have been discussed. The proposed Interest dissemination scheme is briefly elaborated in Section III. Simulation environment and results are analyzed in Section IV. Finally, Section V concludes the paper.

## II. NDN Synopsis and Working Principles

As stated earlier, in vehicular NDN, every node primarily uses three data structures; PIT, FIB, and CS, to forward Interest and Data messages.

- **PIT** {***Name*, *NONCE(s)*, *inFace(s)***}: state of the Interests is stored in PIT. Upon reception of an Interest {*Name*,*NONCE*} from the *inFace*, the *Name* from the Interest is searched in the PIT. If the similar *Name* is present in the PIT with different *NONCE* or *inFace*, the PIT is updated with the *NONCE* or *inFace*, and the Interest is discarded. Conversely, the {*Name*, *NONCE*, *inFace*} are added in the PIT.
- **FIB** {***Name*, *outFace(s) M***}: it is used to forward Interest towards the potential provider(s) in the upstream direction. Based on the *Name* search result from the FIB, the Interest is forwarded to the corresponding *outFace*. Otherwise, the Interest is flooded to all the *outFaces* or discarded, which depends upon the forwarding strategy. The *outFace*'s routing metric *M* indicates its preference to forward the Interest through that *outFace*. If the matched FIB entry has multiple *outFaces*, then the *outFace* with lowest *M* is preferred. FIB is populated with new entries (*outFaces* and *Name* prefixes) using static routes or as per the routing policies.
- **CS**: is Data message cache. Caching of Data messages depends upon the caching policy.
- **Dead nonce list** (DNL): stores NONCEs of the purged PIT entries.

In principle, when a node receives an Interest, it first searches the PIT. If a node fails to find the matching PIT entry, it searches the CS or checks when the node itself is the producer of that content. In case of a producer or successful search in the CS, the node replies with the Data message. If both, PIT entry and CS search fail or node is not the producer, then the message is simply forwarded. In this case, the node records the PIT entry to indicate the Interest is pending. On the other hand, if there is already a matching entry in the PIT, it simply discards the Interest because the node has already forwarded the Interest. When a node receives the Data message, it first searches the PIT and handles the Data message as per the PIT search outcome. The node forwards the Data message if it finds the data name in the PIT. After forwarding the Data message, the node purges the PIT entry. PIT holds the PIT entry for a certain duration if it does not receive the corresponding Data message, called *PIT entry lifetime* (PLT). During this PLT, if no Data message is received, the node also purges the entry. These purged PIT entries either in result of PLT expiration or successful reception of the Data messages are stored in the temporary DNL. When a node receives an Interest, it also checks the DNL. Presence of an Interest NONCE in the DNL indicates that the Interest is either recently satisfied or there is an Interest loop and in result, the Interest is discarded.

There may be the case where the requested content may be available to multiple providers or the content may be generated by multiple producers e.g., sensory or location information of vehicles in the specific region. In this scenario, when the first provider node replies the Interest with Data message, then all the intermediate Data forwarders, between the provider and the requesting node, delete their PIT entries because they successfully satisfied the Interest. Hence, the Data produced by other producers fail to reach the requesting node. There are different solutions in the literature that forward the data from multiple providers or producers to the requesting node and are summarized in the following subsection.

## III. Proposed Named Information Coverage Scheme

In a typical NDN network, the information requesting node sends an Interest and this Interest is forwarded by all the intermediate nodes that have no matching content in the CS. However, when a node with the desired content in its cache receives the Interest, it simply replies the content in the Data message. On the contrary, the CPS system requires the multimodal content from different sources to efficiently take the control decision. Those content providers or producers

[1]Multimodal data is defined as the similar context data produced by different sources. For example, multiple vehicles on a road segment generate their location and engine temperature information.

may be situated within the specific proximity or they may be dispersed in the network. In both cases, the CPS system requires data from all the sources. However, this contradicts to the vanilla NDN's information collection mechanism, where the information producers simply respond with the same requested content to the consumer node. Additionally, these providers do not forward the Interest further in the network to find more potential potential sources. Hence, we proposed the Interest-Data forwarding strategy to maximize information coverage in the NDN-enabled VCPS or named data VCPS (NDVCPS).

Let, a vehicle in the NDN-enabled VCPS requires road or traffic information from different vehicular network elements including vehicles, sensors deployed on the road, and so forth. We denote this vehicle as consumer vehicle, $C$, which is similar to the terminology used by NDN architecture for the node that seeks information from the network. The road segment of which the $C$ is seeking information, is called information discovery region, $S_r$. Initially, $C$ generates an Interest, including name, NONCE ($I_{NONCE}$), and other information. Information name in the Interest message indicates the attributes related to the information that is required to $C$, i.e., road segment name, coordinates, or specific area around $C$, type of information (e.g., temperature, number of vehicles, speed of vehicles, road surface condition, etc.), recency or temporal aspect of information (e.g., current, after 1600 hours, etc.), and so forth. The following name shows that the consumer requires current speed of vehicles within the 1km proximity of $C$.

*/data/speed/current/1km-proximity-C/location-C*

When all vehicles that are in the region receive this Interest, they simply send their current speed in the Data message. Based on this information, $C$ may change its driving mode that includes applying brakes, increasing speed, lowering the vehicle's acceleration, turning on headlights or indicators, and so forth. There may be many vehicles or VCPS elements in $S_r$, depending upon its size. However, in case of vanilla NDN or the schemes like [18] and [19], only few vehicles may reply to the Interest. Consider the scenario (a) as depicted in Fig. 1, where $C$ requires current speed information of all the vehicles in $S_r$. However, only vehicles 1 to 5 are within its transmission range. After sending the Data message, these neighboring vehicles do not forward the Interest any further in the network. In result, $C$ only receives the partial or very limited information about the traffic within $S_r$.

On the contrary to the previous work, the data providers not only respond to the Interest message, but also forward the Interest message further in the network to maximize information coverage in the NDVCPS. Consider, the scenario (b) in Fig. 1, where $C$ sends Interest and all its neighbors (vehicles 2 to 5) reply with the Data message and then they further forward the Interest message in the network to discovery more multimodal information from the network until $C$ receives Data from all the vehicles in $S_r$. To achieve this, the proposed scheme makes the following modifications in the default NDN forwarding daemon.

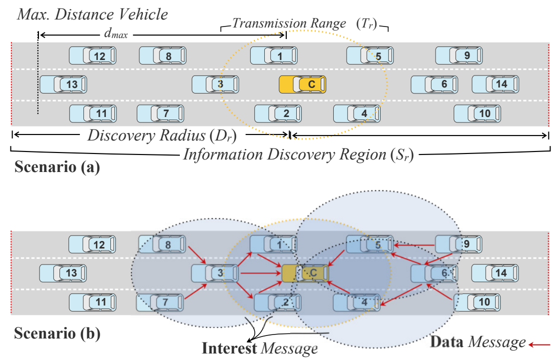


Fig. 1. NDVCPS Scenario with Interest and Data forwarding.

1) In vanilla NDN, Interest message carries the name, NONCE, and optional selectors and security related information, *Interest*{*name, NONCE, Selectors, KeyLocator, ..*}. However, in our proposed scheme, the Interest message contains additional fields; `MultSource` (Multiple Sources) field when set to "1" indicates that the Interest is generated to collect data from different sources. Otherwise, the Interest is processed in the network following the vanilla NDN procedure. `ProdOnly` or Producer only field restricts the Data messages generated by vehicles that are actual producers of the Information or the vehicles that are within the specified region mentioned in the content name. No cached or stale data is replied for the Interest.
2) Each producer computes a random two-byte Data NONCE ($D_{NONCE}$) value and forwards in the Data message. This $D_{NONCE}$ in the Data message helps to differentiate the information produced by multiple producers.
3) Lastly, the PIT entry is not purged until its PLT expires. Additionally, the PIT entry also stores the received $D_{NONCE}$ values of the received Data messages in reply to the Interest of that name prefix.

The forwarding process of the Interest and Data messages by our proposed scheme is discussed in the following sections.

### *A. Forwarding Interest Messages*

When a node receives an Interest message, it first checks the DNL, which identifies that either the Interest message has been recently processed and evicted from the list or not. The Interest message is further forwarded to the next stage that is the PIT verification, if that Interest has not been recently processed by the Interest receiving node. The PIT search process is similar to vanilla NDN, which confirms that either the message is still pending or not. If Interest is found in the PIT, then it is simply discarded because the interest is still pending. Otherwise, the vehicles checks `ProdOnly` field. If `ProdOnly` is set, then the vehicle that can produce the desired content (or the vehicle that is in the information discovery region), simply forms the Data message and forwards it through the same interface from which the Interest is received. Otherwise, it follows the vanilla

NDN's CS search procedure and replies with the Data message depending upon the CS search output if the `ProdOnly` field is zero. Whether the vehicle is producer or not, when it satisfies the Interest message, even then the vehicle forwards the Interest message further in the network depending upon the value of the `MultSource` field.

Even after satisfying the Interest by replying with the Data message, a node may further forward the Interest depending upon the `MultSource` field in the received Interest. In case, the `MultSource` is enabled, the longest name prefix search is performed in the FIB and given the FIB search result, the Interest is either forwarded or negative acknowledgment is sent. Furthermore, if the `ProdOnly` is zero and CS search fails, the Interest is forwarded using default forwarding strategy of NDN. The forwarding process of Interest message is illustrated in Fig. 2. Our proposed scheme adopts the modified set of steps to forward the Data messages, which are briefly discussed in the next subsection.

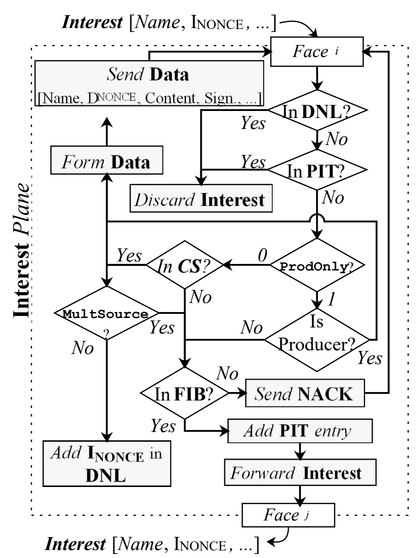


Fig. 2. Proposed Interest message forwarding algorithm in named Data VCPS.

## B. Forwarding Data Messages

The Data messages are generated by the vehicles that are either the actual producers of that information or the provider vehicles that have information in their cache. Forwarding process of the Data messages is modified to meet the maximum information coverage requirement of the VCPS. Similar to NDN, when a vehicle receives the Data message, it first checks the PIT to confirm that the Data is either solicited or unsolicited. Contingent upon the PIT search, the Data is processed further in the forwarding process or discarded. If the desired name is not found in the PIT, which is the case of the unsolicited Data, the message is discarded. Conversely, if the received Data is solicited, with valid PIT entry, $D_{NONCE}$ is matched with the $D_{NONCE}$s stored in the PIT record. This step ensures that the received Data following the respective

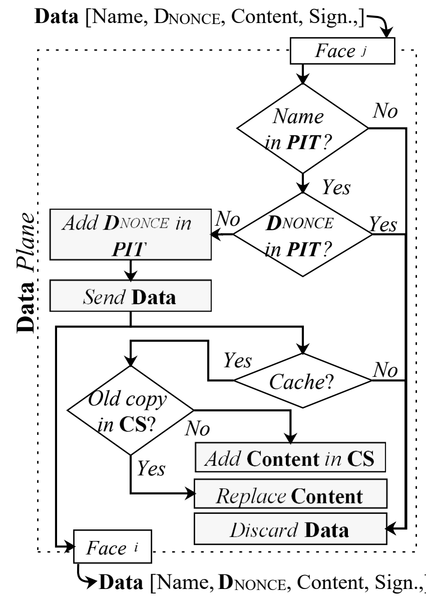


Fig. 3. Proposed Data message forwarding algorithm in named Data VCPS.

Interest has already been received or it is a new Data. The stale or already received Data's $D_{NONCE}$ is already present in the PIT entry, therefore, the duplicate copy of the Data is discarded. Received new instances of the multimodal Data is further forwarded in the network and this new $D_{NONCE}$ is added in the PIT entry. Depending upon the caching policy, the information received in the Data message is cached accordingly.

Here, it is worth noting that the PIT entry is not deleted notwithstanding the new instances of the multimodal Data are received. This ensures the communication of the multimodal data from different producers towards the $C$. PIT entry is purged only when the respective PLT of the PIT entry expires. Moreover, the Data is forwarded through the interface from which the Interest was received or the incoming interface listed in the PIT entry. In order to avoid the Data packet collision, we used the following random contention window base collision avoidance scheme. When a node has the Data message, it first computes the random waiting time, $W_T$, and after waiting for that duration, it sends the Data message.

$$W_T = AIFS[i] + R_{CW} + \tau \tag{1}$$

where, $AIFS$ is the arbitration inter-frame spacing, which is used to prioritize the Data message communication by considering the Data messages in the priority access category $i$, $AC = i$, as in IEEE 802.11p, [20], [21]. To increase the priority of Data messages, we considered $i = 1$. The $R_{CW}$ is the random contention window duration, which is multiple of communication slot duration and $\tau$ is the channel negotiation time. The $AIFS$ for $AC = i = 1$ is computed as:

$$AIFS[1] = AIFSN[1] \times T_{slot} + SIFS \tag{2}$$

The computation of the $AIFS[1]$ involves the AIFS number, $AIFSN[1] = 3$, which is the configuration dependent value and has smaller value for the higher priority communication. The slot duration $T_{slot} = 13\mu s$, that is the backoff time unit of IEEE 802.11p with 10MHz channel spacing. Next, the $SIFS$ is the short interframe space equal to $32\mu s$, that is sufficient time duration between high priority frames.

The random contention window $R_{CW}$ is used in the $AIFS$ to avoid collision between Data packets and estimated as:

$$R_{CW} = rand(0, CW_{max}[1]) \times T_{slot} \tag{3}$$

In above expression, $CW_{max}[1]$ is the maximum contention window for access category 1 communication and calculated as $CW_{max}[1] = \left(\frac{CW_{min}+1}{2}\right) - 1$, where $CW_{min} = 15$. Here, we only considered the maximum contention window for the $AC = 1$, $CW_{max}[1]$, which shows that there is no acknowledgement or retry mechanism involved in case the Data message fails to reach the downstream node. Finally, the $\tau$ duration is added in the random waiting time to compensate the channel negotiation, because multichannel model is adapted by the IEEE 802.11p [20].

The effectiveness of our proposed scheme is measured through simulations and compared with its close counterparts in the literature. The simulation environment and performance measures are briefly discussed in the next section.

TABLE I
SIMULATION PARAMETERS

| Simulation Parameter | Value |
|---|---|
| Communication Interface | IEEE 802.11p |
| Data Message Size | 100 bytes |
| Interest Message Size | 50 bytes |
| Transmission Range ($T_r$) | $300, 400, 500, ..., 900m$ |
| Max. PIT Entry Lifetime | $4s$ |
| Interest Rate (IR) or Interests per second | 1, 3, and 5 |
| $C$ | $1, 3,$ and 5 |
| Information Discovery Radius, $D_r$ | $1Km$ |
| Simulation Duration | 500s |

## IV. SIMULATION ANALYSIS

The simulation results of the proposed scheme are critically analyzed in this section. Performance of the proposed scheme is compared with the scheme that was proposed for collecting information from multiple sensors within transmission range (single hop) of the consumer [16], [17], which is referred here in as the conventional scheme. This conventional scheme simply sends Interest and does not discard the Interest from its PIT until it collects Data from all of its one-hop neighbors. However, no mechanism has been proposed to collect multimodal data from sources that are multi-hop apart from the Interest generating node.

All vehicles in the network use proposed named data forwarding scheme over IEEE 802.11p to communicate with other vehicles. The performance of the proposed scheme is compared for different transmission ranges, i.e., 300, 400, to $900m$, where the diversified number of information requesting nodes $C$ is considered in the simulations; $C = 1$, 2, and 3. Total highway road segment size is $10Km$. All vehicles are moving at the average speed of $55km/h$ over the 4-lane two-way road. Every consumer discovers the information for exactly $2s$ and the results of the complete discovery duration of all $C$ are summarized below. Throughout the simulations, the information discovery radius of $1Km$ has been used ($D_r = 1km$). Individual $C$ generates Interest at varying rates (Interest rate-IR) that varies from 1, 3, and 5 Interest per second. Rest of the simulation parameters are enlisted in Table I.

The performance metrics that are monitored during simulation and contrasted with the conventional scheme, are as follows:

- *Information discovery ratio (IDR):* is the unique number of Data messages received in response to the Interest generated by $C$ from the vehicles within $S_r$ divided by the total number of vehicles within $S_r$. IDR increases, if the Data message from more number of nodes within the $S_r$ is received by $C$. This can be achieved by efficiently forwarding the Interest towards many nodes in $S_r$.

$$IDR = \frac{\text{Received Data msgs. from vehicles in } S_r}{\text{Total No. of Vehicles in } S_r} \tag{4}$$

- *Maximum information coverage distance ratio (MICDR):* represents the proportion of the farthest distance node from which $C$ has successfully received the information and the discovery radius $D_r$.

$$MICDR = \frac{d_{max}}{D_r} \tag{5}$$

- *Forwarded Data Messages:* is the total number of Data messages forwarded in the network.

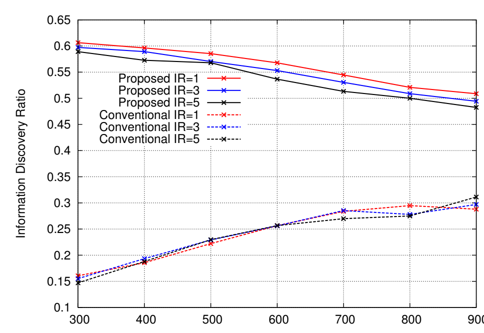


Fig. 4. Content discovery ratio for varying transmission ranges, $T_r$, with 3 consumers and interest rate of 1,3, and 5.

### A. Simulation Results

Initially, we analyzed the IDR of a network scenario with 3 consumers and $IR$ of 1, 3, and 5 versus different transmission ranges is shown Fig. 4. There are three things that are worth noting here including; (a) large IDR of the proposed scheme compared to the conventional scheme, (b) impact of large

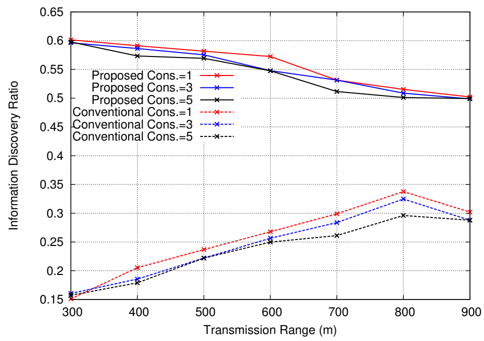


Fig. 5. Content discovery ratio for varying transmission ranges, $T_r$, with 1 interest per second and different consumers.

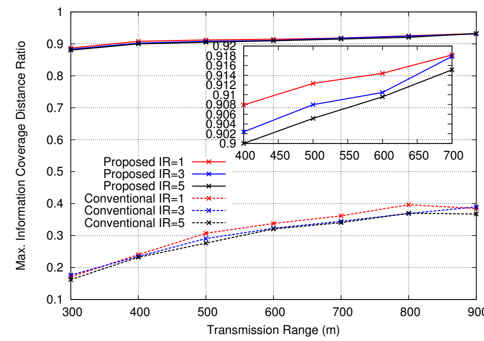


Fig. 6. Information discovery distance ratio for varying transmission ranges, $T_r$, with 3 consumers and interest rate of 1, 3, and 5.

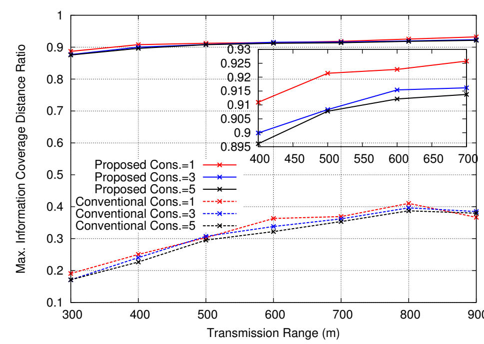


Fig. 7. Information discovery distance ratio for varying transmission ranges, $T_r$, with 1 interest per second and different consumers.

transmission range on the IDR, and (c) effect of different $IR$ on the IDR. Information discovery in the conventional scheme is just restricted to one hop and that is the reason that a small fraction of nodes just send information towards $C$. On the contrary, the proposed scheme propagates Interest further in the network and many nodes within the $S_r$ reply with the Data message. Accordingly, the proposed scheme has a very large IDR, which is almost $400\%$, $200\%$, and $165\%$ larger than the conventional scheme for $T_r$ of $300m$, $600m$, and $900m$, respectively. Next, it is evident from the illustration that IDR of the proposed scheme slightly decreases and for the conventional scheme it gradually increases as the $T_r$ increases. This is only because many nodes in $S_r$ generate Data messages, which is large in size. Hence, most of the Data packets fail to reach multi-hop distant $C$ due to large packet collision. As the $T_r$ reaches closer to $D_r$, almost all the vehicles in $S_r$ can communicate directly to $C$. Lastly, the effect of different $IR$ can be seen in the figure, where one interest per second, $IR = 1$, has slightly large IDR than the $IR = 3$. The main reason behind this phenomenon is that large $IR$ results in more Data that leads to frequent collisions and Data loss. As a result, IDR is slightly smaller for large $IR$. On the contrary, there is not much impact of $IR$ on the conventional scheme because it simply seeks Information from one hop neighbors.

The IDR for multiple consumers with $IR = 1$ for varying transmission ranges is shown in Fig.5. Varying transmission range has similar impact on IDR of conventional as well as the proposed schemes, as discussed previously. A significant variation in the IDR of the conventional scheme can be seen for different number of consumers and large $T_r$. For large number of consumers with larger $T_r$, the collision probability increases and consequently the IDR becomes low. To conclude the discussion related to IDR, we can easily conclude that the proposed scheme has multiple times large IDR than the conventional scheme for any $T_r$, the number of consumers, or $IR$.

Next, we analyzed the MICDR for different $IR$ and number of consumers and shown Fig. 6 and 7, respectively. It is apparent from the results that the proposed scheme has more than $90\%$ MICDR, which means that it receives information form the farthest nodes in the $S_r$. On the contrary, the conventional scheme fails to receive information from the distant nodes. Even though, for the large $T_r = 900m$ that is almost near to the $S_r$, the conventional scheme could not receive information from the distant nodes. One of the reasons for this small MICDR is the large collision of Data messages at the consumer when it receives from varying distance nodes. In results, the maximum MICDR achieved by the conventional scheme is approximately $40\%$ of the $S_r$ for any $T_r$. Furthermore, an identical impact of different $IR$ and consumers can be seen in the inset plots of Fig. 6 and 7, as discussed previously.

Finally, we discuss the number of Data messages processed within the conventional and proposed schemes for varying $T_r$ and shown in Fig. 8. It is obvious form the figure that the proposed scheme process large number of Data messages because it discovers information from many nodes within the $S_r$. Respective to $IR$, the number of messages processed in the network increase accordingly. This validates the fluctuations in the previous results (IDR and MICDR) caused by varying $IR$ and consumers. Another reason for this large number of Data messages processed in the proposed scheme is that every vehicle forwards the Data message that it receives from the upstream vehicles. This Data message overhead can be

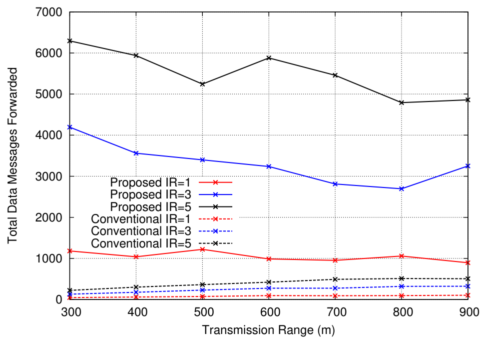


Fig. 8. Data messages forwarded for varying transmission ranges, $T_r$, with 3 consumers and the Interest rate of 1, 3, and 5.

reduced by using the message holding defer concept where nodes hold and defer the communication of the message when it receives multiple copies of the same message from different nodes.

To summarize the above discussion, our proposed scheme discovers more information (high *IDR*), and it discovers information from the farthest nodes in $S_r$ (large *MICDR*), compared to the conventional NDN-based multimodal Data discovery scheme.

## V. Conclusion

In this paper, we proposed the communication model for the multimodal information for named data vehicular cyber-physical system. This is the first time to integrate CPS and NDN for the vehicular communications. Our proposed Interest forwarding scheme discovers about $400\%$ more traffic information from approximately $90\%$ of the information discovery region. Due to large information discovery and coverage, the proposed scheme forwards large amount of Data messages. Hence, in future, we further investigate on reducing the Data overhead by adapting the holding time and packet deferring methods to alleviate the Data communication overhead. Furthermore, we intend to analyze the effect of mutlimodal information dissemination on the communication delay, Interest broadcast overhead, and other network performance metrics.

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