**Review Article**

# Data delivery techniques in content centric routing for IoT: a systematic review

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## Abstract
*Internet of Things (IoT) connects a number of devices that share data through the internet. Communication between these devices causes a large amount of data in the network that creates a lot of traffic. In order to manage the traffic, the concept of content-centric networking (CCN) is introduced and identified as an effective network model for efficient data delivery in a wireless sensor network. CCN determines routing path based on the content. In this paper, we discuss the CCN architecture and its packet forwarding mechanisms. Also, we provide a review of different techniques of CCN covering naming schemes, architecture and the parameters evaluated and discussed in recent state-of-an-art. This review analysis may help the new researchers to go in-depth in the domain of CCN.*

## Keywords
*IoT, CCN, Naming, Architecture, Message, Routing.*

## 1.Introduction
IoT is a network of communication in which physical devices are connected to each other through the internet where they share data that can be accessed anywhere at any time [1]. Wireless sensors networks (WSNs) are considered to be the most important element of the IoT. It plays an important role to support the communication between user devices and large-scale resource-constrained devices such as sensors and other smart devices. Some of the applications such as smart building monitoring, healthcare, environmental monitoring, production control, security and surveillance applications. Traditional routing protocols aimed to support host to host communications among nodes that are distinguished by an IP address fails in a distributed wireless network as a result of frequently changing network topology generated through mobility of node and regular link failure. Moreover, IoTs comprises of heterogeneous devices and most of these devices are small, low power with a limited memory, low cost, and constraint-oriented wireless sensors.

Data is not available most of the time, due to low memory and low battery lifetime.

To overcome the problem, the CCN paradigm is used which rely on content-based forwarding and in-network caching for sending the packet data in the wireless network, which significantly saves the energy and bandwidth, reduces network latency and extends the network lifetime in a resource-constrained IoT network environment. The main features of CCN in the wireless environment are discussed below:

First, user mobility is inherently maintained in CCN: when a user moves from one place to another, it issues any Interest that is not satisfied again from the new location. Provider mobility also needs updates of the routing table, but CCN intrinsically promotes multi-sourcing the content [2]. In CCN, mobility can be provided using Publish-Subscribe model, through which any mobile node subscribes the network for the information it needs and the publisher advertises the availability of information to the network [3]. Hence, the CCN Mobility support can play an important role in vehicular ad-hoc network (VANET) and mobile ad-hoc network (MANET) applications.

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A second important feature of CCN is in-network caching, which reduces the network load while caching the data to the intermediate nodes. And thus, cache enabled IoT applications can improve network performance.

Another is receiver driven communication, where CCN data retrieval is receiver driven and the communication only starts when a consumer wants. To get some data, a receiver places a request and the network finds the best possible source for the requested information. There are two approaches, through which a receiver can receive information: (i) coupled approach and (ii) decoupled approach. In a coupled approach, name resolution and routing are aggregated and the data is routed following a reverse path towards the consumer. The name-based routing (NBR) is involved with this approach for the content discovery. While in the decoupled approach, the Name Resolution and routing are performed independently and any path other than the request message is utilized to forward the response to the consumer. A Lookup based resolution system (LRS) can be used for the implementation of such an approach.

The fourth advantage is that CCN deals with alternating, dynamic topologies and short-lived connectivity in wireless network environments.

Other evolving applications are associated with exchanging of surveillance information and updates in the software of the mobile user in MANET. In the same way, in VANETs, the traffic information and climate information required by vehicles for a specified range, irrespective of their identity or IP addresses. Different scientific and military applications constructed on data gathering and data distribution in a wide-scale monitoring wireless sensor networks, that can help in naming content and the Interest/Data exchange in CCN.

This paper focuses on the CCN model, and it gives a complete outline and a survey of the applicability of this model in a wireless network. The rest of the paper is structured as follows: Section 2 covers CCN overview in which CCN integration with routing protocol for low-power and lossy networks (RPL) and architecture with the routing and forwarding mechanisms is discussed. In section 3 we present the discussion on data delivery with content centric routing (CCR) in IoT. Section 4 discusses about the challenges and research solutions in brief and Section 5 concludes the paper.

## 2.CCN overview
### 2.1CCN integration in RPL
The integration of CCR components in the RPL protocol is described with the complete system architecture as shown in *Figure 1*. The integration of CCN communication layer in RPL requires a Named Data to design and implement the protocol based on CCN. For the integration of this communication layer in RPL, the Contiki operating system is used which mainly deals with the embedded system and WSNs. The communication layer in CCN comprises of a stack and a driver, which meets the implementation style of Contiki. The CCN processing, forwarding and caching functions can be implemented using Stack, while the message exchange in the lower layer is handled through drivers.
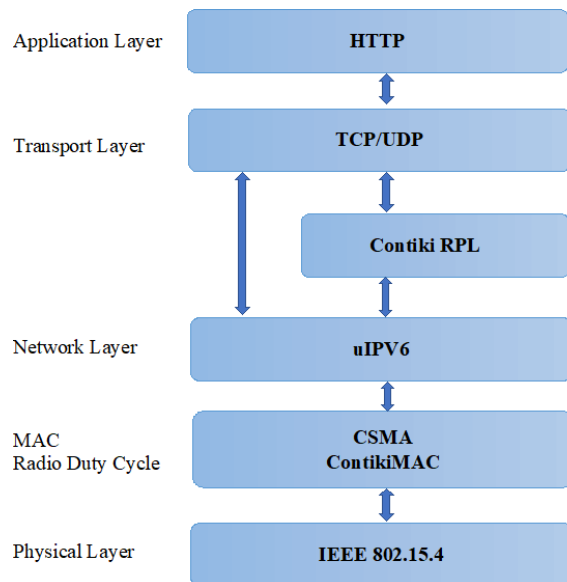


**Figure 1** CCN integration into Contiki RPL [4]

The communication layer in CCN directly uses the MAC layer already existing in the Contiki to transfer its data messages, and hence it handles the packet transmission to deliver messages which does not depend on other transport protocol.

### 2.2CCN architecture
The CCN architecture is formed on named data in which the content request is identified through names of the content and not with their location. The CCN method tends to the problems constraining the existing utilization of systems by expanding the accessibility of information. To reduce the traffic congestion, it provides in-network caching. While in terms of security, CCN proposes that trust based on content is simply lost when we depend on the

location of the data. Rather than which, it incorporates the security with the network at the data level. Moreover, the location and content have no mapping, as the communication depends only on data names. So, it is simple to configure the network devices. The CCN protocol is used as a transport protocol in CCN network architecture.

### 2.3CCN messages
### 2.3.1Message types
There are two types of CCN messages :(i) Interest Message (IM) and (ii) Content Object (CO) message. The IM is a request of the named data. It contains the full name that identifies a piece of content. Interest packet may also contain a prefix of the content name as shown in *Figure 2*. A possible reply to the Interest can be a prefix of the Interest name that matches the content.

The CO message is utilized to provide data and it comprises of a data headed by the content name.
### 2.3.2Message formats
The physical and MAC layer uses IEEE 802.15.4 standards for implementation in Contiki which is integrated with the CCN communication layer. The frame size of an 802.15.4 is restricted to 127 bytes. And a payload of 72-116 bytes is available after the framing at the link layer, rely on various addressing and security option.
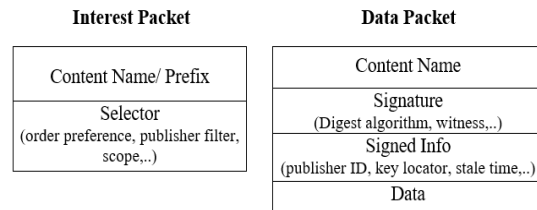


**Figure 2** CCN message format [5]

### 2.3.3Message exchange
An IM is broadcasted over the network connectivity with reference to a consumer requests for content in a one-hop node of the multi-hop wireless environment. The nodes receiving a message and having the requested data that matches the Content name or prefix may transmit the corresponding CO message. An Interest that matches the Data can only be transmitted in reply.

For an individual established Interest message, a node will transfer a response with compulsorily one CO message, even though the node contains various similar COs. This mapping among IMs and Content messages keeps stability in the flow that lets the receiver to manage the speed of the data transferred from a sender. It saves the bandwidth by transferring

the data where it is not requested.

Unsatisfied IMs are retransmitted in some fix time interval for a reliable delivery. A timer is maintained at the receiver side for the unsatisfied Interests and to transmit it again when the timer expires.
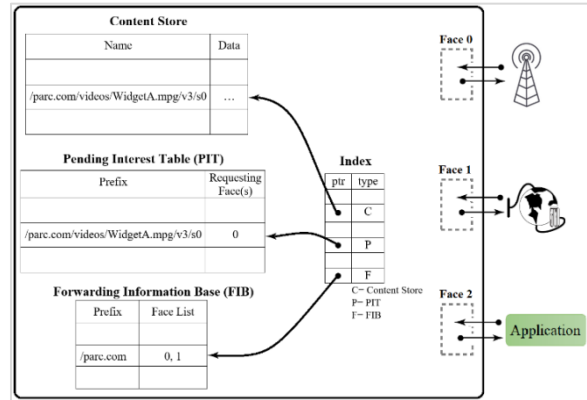


**Figure 3** CCN node model [6]

### 2.3.4Node model
A node model involves following the data structures, according to the specifications of CCN to offer caching, response to the content requests and to direct messages to different nodes in the network [4]. The index table is a pointer to the data structures table discussed below.

Face: A face is a basic overview of an interface. In the context of specifications of CCN, a face can be a link to a network or it can be a link directly to an application as shown in *Figure 3*. It can be set up using a tunneling mechanism using P2P (point-to-point) addressing for transmitting and accepting data on a particular network as well as to broadcast messages. In a wireless sensor network, a node comprises of a single network interface controller.

Content Store (CS): The CS can also be called as a cache where data is stored. It also holds the COs formed locally via the information gathered by sensor devices and also the COs acknowledged from other nodes. An index pointer is used to enable content retrieval and suppression. It is not essential to take any distinct procedures to preserve CO messages in a CS as it is a cache and not a permanent store. On receiving a different value of data, the data in CS is updated with the current content.

Forwarding Information Base (FIB): A FIB table comprises of a prefix and a face identifiers list as shown in *Figure 3*. The FIB table is organized to

retrieve the longest prefix match scheduled on names. A prefix entry in a FIB table is a pointer to a set of destinations instead of a particular one. To retrieve a matching content, a FIB table shows a list of faces that directs its Interest message to a node which is a process equivalent to the IP routing table. A node will direct an Interest to minimum one of the faces whose identifier is involved in the index of FIB table, to retrieve data that matches the prefix.

Pending Interest Table (PIT): PIT is a source table considering the Interests that are not satisfied. It is structured to retrieve a full prefix pairing on names (a match is obtained only when a prefix interest completely matches the prefix of PIT entry) by lookup. PIT entry points to a list of face identifiers which are sources of the undetermined Interest.

As IMs are broadcasted in the network towards possible origin of leaving data, from the intermediary nodes, the PIT entries mark the path of a corresponding data packet that gets back to range the original request for the content. The IMs are routed in CCN, in this manner. Once a node discards the data packet or receives content data which pairs with a pending Interest, a matching PIT entry is forwarded to the corresponding Data packet which is then removed from the table.

PIT entries are maintained temporarily so, it times out after a specific period of time. When pending Interests does not find a corresponding content, it expires and is later removed from the PIT. It depends on the consumer node, to request the Interest message again if it is concerned with receiving the content data. Here we note that the requester of the data preserves the track of Interest messages in its PIT and sends face identifier 0 to use it.

### 2.3.5 Routing and forwarding

In CCN routing and forwarding the packets can be considered as a smart operation in a wireless environment, routing process can be considered as the way FIB table is filled by interchanging the prefix name by publishing among the routers while Forwarding states that the processing of interest and data that is done hop by hop. Initially, to fill the FIB tables the CCN nodes can use any traditional routing protocols. It generally depends on flooding-based methods to find the data content in a wireless network. The basic flooding-based methods for data distribution in CCN can be introduced with some selection of the CCN forwarding decision process. There are two forwarding approaches blind and aware [7].

In blind forwarding, it mainly supports flooding, which is the simplest method to direct the Interest packets in the wireless network. Some distributed packet suppression techniques can be used as a solution to the packets redundancy and collisions. The blind forwarding does not always ensure that the best nodes are designated to packet forwarding; hence a more advanced, aware forwarding approach was introduced.

In aware forwarding, some awareness mechanisms are included to select the outgoing interface and the next hop nodes based on some selection criteria.

**Interface selection** is based on the criteria in which forwarding CCN packets may use the data kept in PITs and FIBs for the selection of outgoing interface(s) at a single node. For instance, the FIB may preserve the path of the delivery performance (in terms of latency, cost) of each interface leaving, to transfer the data packets through the best interface [8].

**Next- hop selection** where a CCN node can also use some awareness for the selection of subsequent hop in Interest forwarding/ Data forwarding. BlooGo proposal [9] determines whether to forward the packet or not, by comparing the neighbouring of the sender and receiver which can be done using Bloom filter with the data packets.

**Path selection** is done where the Interest requested by consumer propagates through multiple paths towards the multiple data provider, and also the data packets can return through various paths when several replicas of content data are cached in the intermediate nodes in the network. The diversity of data over various paths is utilized in a VANET [10]. Through some coding techniques of the network, where intermediary nodes make a linear combination of the data established, and transfer the outcome to their neighbouring node.

**Provider selection** is considered when a consumer gets more than one source for the content requested. The best provider of the content data is selected on some criteria. In [11], the provider selected is advertised with successive Interests that consequently routes the packets to the intermediate nodes. Light path-state information is the provider's identifier selected and the hop distance to the receiving node involved in Interest and Data. That is kept as the fields in a provider table of the CCN nodes in the wireless ad-hoc network. That gives a dual benefit of

controlled channel load and low energy consumption.

# 3. Discussion on data delivery with CCR in IoT

The recent researches in CCN for IoT are varied in different environments and application area. The CCN or named data networks (NDN) which aims to caching and subscribing data on the basis of content instead of the host. Also, the data access is independent of location, which enables in-network caching resulting in reduced network traffic [12, 13].

MobCCN protocol [14] is proposed for routing and forwarding mechanisms, with their performance evaluation with the different network traffic loads. Different naming and caching schemes for deployment of the CCN are discussed [15].

Hierarchical naming is used in NDN and CCN approaches. To name the contents, the hierarchical structure is followed which is similar to the URLs in the web pages. With the present Internet applications, Hierarchical naming provides a better compatibility and also provides name aggregation.

The other naming scheme is flat names that are of any fixed size and are easy to operate in routing as it takes fewer resources for computing, and consumes less amount of space while saving. In [16], the flat naming scheme for Wireless networks is proposed in which the naming scheme is divided into two parts: the initial part is used to find category and second is used for content. Also, they explored the CCN naming mechanisms in Contiki OS and the results show the naming mechanism presented performs better than IP in terms of energy consumption and network delay.

In, [17] authors have proposed a hybrid naming scheme for Smart Campus. Hierarchical and Flat components are combined in a Hybrid naming scheme. The naming scheme proposed takes the domain name, location and task as hierarchical component and a hash of device name and data as a flat/hash component. The proposed naming scheme is implemented in Contiki OS.

The evaluation of the execution of CCN is implemented with data transfer efficiency and content distribution efficiency [6] with the usefulness for both content distribution and point-to-point network protocols that was released as an open source. Design and implementation of stateless multicast RPL forwarding (SMRF) algorithm for IPv6 wireless sensor networks using trickle algorithm is demonstrated with the performance and energy consumption [18−21].

*Table 1* provides the comparison of various research projects, evaluated with the naming scheme, architecture and the parameters evaluated with the simulation platform and the programming language used in the implementation.

**Table 1** An overview of CCN research projects

| Ref. paper | Naming scheme | Architecture | Parameters evaluated | Simulator(Os, Language) |
|---|---|---|---|---|
| [4] | Hierarchical | CCNx | Average delay with cache enable & disable | Contiki OS and Cooja Simulator |
| [19] | Hierarchical | CCN | Throughput, success ratio | NS-3 and CCNx |
| [20] | Hierarchical | CCNx | Latency of CoAP over CCN | Contiki OS and Cooja Simulator |
| [6] | Hierarchical | NDN | Content retrieval time & data overhead for pedestrian & vehicular scenario | NS-3 Network Simulator |
| [16] | Flat Name | CCNx | Average energy consumption | Contiki OS and Cooja simulator |
| [22] | Hierarchical | CCN | Overhead for generating IM and CO. | C Language |

# 4. Challenges and research solutions for CCN

In this segment, the issues with the possible solutions for future research directions that need to be solved by researchers are presented briefly.

## 4.1 Naming
Hierarchical naming is generally used in CCN based IoT naming. Also based on application demand the naming differs. The packet header size is fixed length [23]. The general idea is to show the hierarchy of the naming components that classify the application and the attributes that define the associated contents. The

CCN naming is still under dynamic research, and a few naming proposals in context with the wireless networks have appeared as a part of the application domain. Flat names [5] can be obtained by applying hash algorithms to already existing contents and are not applicable to the dynamic contents, whereas hierarchical names provide the request of dynamic IoT contents that are created on demand (e.g., a parameter measured by a sensor), only if the naming conventions are stated in the system configuration.

### 4.2Caching
Though caching is a distinct feature of CCN for IoT, it has gained a lot of attention by researchers. It is useful to speed up content retrieval and increase data availability. The cache decision and replacement policies are taken into consideration for various research perspectives [24]. Although caching operations are relatively expensive with respect to processing and bandwidth consumption. Mostly these policies show the issue of usage of space with content popularity. The CCN based caching schemes also include the freshness value of the content to choose the caching contents. Though the content popularity is also included in the policies it is still required to explore new methods for content popularity [25].

### 4.3Security
Security is the most demanding research issue that needs to be undertaken in CCN. Most of the CCN security-related solutions are provided for the wired topology and the sensor networks still need to be configured for the security by the research community. The PKI (Public Key Infrastructure) is very complex to implement as it requires more power in the implementation of trust management and key generation in constrained oriented devices [19]. The main drawback in context with key management requires the pre-distribution of keys that creates inflexibility. Usually, the CCN functions for security should be flexible enough in the choice of different cryptographic methods that can be chosen based on different applications and device capability [5].

## 5.Conclusion and future work
The literature survey provided primary CCN design keys to fulfill IoT requirements and open research opportunities. But an important question still remains regarding the practical deployment of CCN. Generally, CCN solutions are deployed as an overlay over the current IP network or it can be implemented directly using clean-slate solutions to substitute current IP. Due to the complexity, in the overhead and encapsulation with IP protocol, the overlay

solutions are generally not preferred, but it can be used as per the application requirement. A clean slate solution can be deployed easily as there is no requirement of communicating with IP nodes or to preserve backward compatibility. With reference to the design deployment of CCN, lets the coexistence of IP technology that can be facilitated by CCN hierarchical names that are similar to the URLs of web pages. Hence, we can say that CCN has the potential to provide a network solution for IoT. In this review paper, we emphasized on the core concepts of CCN and discussed the different methods of routing and packet forwarding techniques. Also, we have discussed and presented a literature survey on CCR techniques and their comparisons to identify the suitability of them under different environment. It has been analyzed that various important parameters such as delay, throughput, latency and energy consumption can be handled efficiently by the appropriate selection of any of the technique. In addition, future work may involve developing an alternate intelligent technique that can further handle above-mentioned parameters efficiently.

### Conflicts of interest
The authors have no conflicts of interest to declare.

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