An Overview of CCMANET: Content Centric MANET

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Abstract. Due to CCN has the advantages of content-centric, unstructured, chunk-level and multipath, the Content Centric Mobile Ad-hoc Network (CCMANET) applies the advantages of Content Centric Network (CCN) to Mobile Ad-hoc Network (MANET). The method solves the problems of low efficiency and unstable in transmission, which caused by nodes movement, dynamical changes of topology, limited node capacity, instability of wireless channel. This paper provides an overview of the existing technologies in CCMANET. Firstly, the paper introduces the basic principle and the new features of CCMANET. Secondly, the key techniques, such as caching, routing, mobility management and security are visited. From this, some important remaining challenges are raised.

Keywords: CCMANET · Content centric network · MANET
Routing · Mobility management · Security

1 Introduction

Mobile Ad-Hoc Networks (MANETs) [1] can provide efficient content sharing among mobile nodes (MNs), but there are many shortcomings that limit the application of the MANET in practice. MANETs are composed of MNs autonomous network, equipped with wireless communication interface, between nodes can communicate directly, without relying on any infrastructure. The network is particularly suitable for self-organizing mobile scenes, including battlefields, vehicular networks and disaster recovery [2, 3]. However, routing uncertainty and flexibility caused by node mobility will pose a huge challenge to MANET. At present, traditional wireless protocols and IP networks tend to perform poorly due to high mobility and compromise channels. So safe and reliable content distribution is a key challenge in a destructive environment.

Based on the traditional network, the researchers have carried out extensive research on various forms of MANET [4, 5]. However, the traditional host-based transport mechanism limits the mobility management of the supporting nodes.

B. Li et al. (Eds.): ChinaCom 2017, LNICST 237, pp. 72–81, 2018.
https://doi.org/10.1007/978-3-319-78139-6_8

As most of the MANET applications are “content-centric” information sharing, such as picture, video, etc., don’t care about the content hosted in which node and provided by which node. Therefore, the content delivery efficiency of the MANET is expected to be improved effectively by using content-centric routing protocol than using host-centric TCP/IP routing protocol. To validate, some researchers [6–8] have used the idea of content centric network (CCN) to MANNET, and proved that the method is a reasonable and effective.

CCN as a network example [9], its purpose is to allow content and services such as access and transmission of resources to become the basic driving force of network design. CCN uses the content name as the address instead of the IP-based host address. It publishes the content request primarily by broadcasting, including the interest grouping (IntPs) of the name of the requested content. Its IntPs is the node with the data, through the intermediate node to the sender of the request to send data packets (DatPs). The requesting node is able to receive multiple answers and select the “best” answer. Each node used to transfer data is able to cache data for the same local request. The local cache distributes the same content across multiple nodes, so the requesting node can retrieve the content from multiple nodes and select the best node to transmit the data. This basic paradigm “decouples” the resources with the hosts on which it resides, enabling the network to efficiently locate and deliver the resources requested by the endpoint.

Reference [10] investigated ad-hoc networking via CCN, and the authors of [8] designed a video sharing system of Smartphone over content-centric networks, their results demonstrate that the CCMANET is stable and reduce traffic overhead. In order to improve the performance of CCMANET, a lot of researches about the caching, routing, mobility management and security have been carried on. Moreover, in [11], the CCN was introduced into the military network and emergency MANETs. Experimental results, CCN can provide simple content search and system delivery in battlefield and first aid situations.

The main purpose of this paper is to overview of the CCMANET. The basic structure of the rest is as follows. Section 2 mainly introduces the basic principle and characteristics of CCMANET. Section 3 visits the key techniques of CCMANET. Section 4 presents several challenging research directions in this subject, and finally Sect. 5 concludes this paper.

2 CCMANET: Content Centric MANET

In this section, we review the general concept of CCN, and introduce the principle and features of CCMANET.

2.1 Content Centric Network

In the CCN, each node maintains three data structures, including content storage (CS), forwarding information base (FIB), and pending interest table (PIT). When a node needs content, it only broadcasts a request packet, called the Interest package, which contains the content name. When a node receives an Interest, it first searches for the contents of the locally cached content of the CS content and matches the content. If it is found, which will send a DatP as a reply. Otherwise, PIT try to see if the pending request is waiting for the same content by matching. If a match is found, the new interface identifier is included in the PIT. When a DatP is received, it will be sent on all node interfaces with entries in the PIT. If both CS and PIT can't match, the node will search in FIB. If a match is complete, the node appends a new entry to PIT and forwards the interest. Data forwarding is simple; the packet follows the interest chain to return to the original requester. Each node that transmits data performs data caching later for the same local request.

CCN mainly through the host from the separation of resources, and focus on data transfer rather than end-to-end coverage. Because of this innovative concept, CCNs are expected to benefit from efficient MANETs retrieval and generate new interest.

2.2 Basic Principle of CCMANET

In CCMANET, if the node is interested in its contents, the node will broadcast IntPs to all its neighbor nodes, as illustrated in Fig. 1, step ①. The name of the content is included in the IntP.

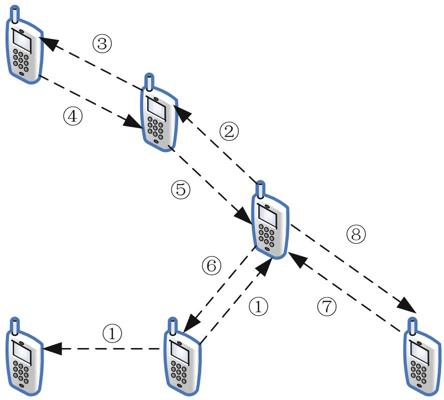

Fig. 1. CCMANET overview

Any node that receives IntP does the following: (1) To send the DatP and discard the IntP, if the content is in the Content Store; (2) To discard the IntP, if IntP has been seen; (3) If you do not see IntP, IntP adds an invisible entry to the PIT and forwards the interest to the neighbor node (steps ②–③).

When a node receives the interest, any content node that contains its content store will issue a DatP with a name that matches the name in IntP. DatP is forwarded to the node of interest (step ④).

Any node that receives DatP will follow the following behavior: (1) The DatP is relayed to the interface of the upstream node according to the DatP content name (steps ⑤–⑥) on the PIT. If you are interested in forwarding DatP, delete interest in PIT.

(2) According to the cache strategy, decide whether to cache or cache the contents of the Content Store. If the cache is available, the subsequent request for the same object can be answered from the node (as shown in steps ⑦–⑧, as shown in Fig. 1).

2.3 New Features of CCMANET

CCN can provide some benefits for MANETs, and is a host-centered effective alternative to the Internet paradigm, but this will not be conducive to the dynamic nature of the mobile environment. In CCMANET, the mobile node can communicate according to its own required data, rather than calculating a specific path for a particular node. This greatly simplifies the implementation of CCMANET, and has the following new features.

First, the CCN paradigm eliminates the need to assign an IP address or identifier to each node; the node can transfer Interests and DatPs to each other through the application data name. Static configuration is not possible because nodes such as node mobility and Mobile IP are unsatisfactory [12]. Therefore, the CCN paradigm is very useful in dynamic environments.

Second, there is no routing loop for this data name-based design, so IntPs can forward multiple routes to multiple data paths; by analyzing the requested data in multiple directions, the node can evaluate which path gives Out of the best performance, and only to the future direction of interest to send the same interest. This multi-path approach eliminates the critical dependency on a single path that is precomputed, and the routing update and routing state consistency between all nodes are not critical.

Third, in-network caching and cache fragments of application data techniques can be match the nature of MANET. For MANET, in the mobile environment, the traditional cache method can't meet all condition that the stability of the routing path and the byte cache node to obtain the exact path to follow the packet. Therefore they can't work properly. On the contrary, in the CCN, even if the path is neither stable nor predictable, CCN can also be implemented cache. In view of the uniqueness of the identity of the content, if the other node requests it, it can also be reused and can be cached in any node that forwards it.

Finally, the CCN itself can support asynchronous data exchange between end nodes. When internal caching data is used, the mobile node can be used as a link between the disconnected areas, and can be communicated even in the case of intermittent connections.

3 Overview Existing Key Technologies of CCMANET

Extending the CCN paradigm to MANETs will mainly lead to scalability and mobility-related issues, so these issues must be properly addressed. Therefore, many investigators have done some researches on the key technologies of CCMANET and acquired many novel accomplishments. In this section, we will anatomize and conclude researching achievement in the way, so as to impel the relative research to be in deeper development.

The CCMANET mainly includes the following 4 technologies. The purpose and characteristics of each technology are as follows in Table 1.

Table 1. Purpose and characteristics of the four technologies

Technology	Purpose	Present situation and characteristics
Caching	The CCMANET is to provide efficient content retrieval to mobile nodes without the support of any communication infrastructure. As a result, efficient caching schemes in CCMANET are of significant interests	Combining CCN with MANET is one of the keys to CCMANET. Because CCN and MANET can't use caching schemes in CCMANET, this also poses new challenges for CCMANET's caching solution
Routing	In the CCN, when the node chooses an interface to broadcast IntP, the corresponding DatP follows IntP's bread-traces and returns to the data consumer. Therefore, the CCMANET efficient forwarding design is of great significance	In CCMANET, one challenge is that torrents will cause additional bandwidth and power consumption; another challenge is the caching of clips. In a typical MANET deployment, a node uses only one interface, and the interface selective design causes all nodes to flood all of the IntPs it receives. At the same time there is no predictability of IntP destination connectivity and block completion status, so the existing single-path routing algorithm will continue to find the first location to send data packets, and ultimately may lead to most of the IntP re-overflow
Mobility management	To assess the effects of the node mobility of CCMANET	The mobility of the source node (SN) and the client node (CN) is the two main mobility types of CCMANET
Security	The CCMANET mainly through its unique name to protect the content itself, in other words to ensure that it claims a content item. Therefore, CCMANET for the application of security issues, mainly from the content of the manufacturer's trust and data integrity of the two aspects to consider	Theoretical analysis, any node has the ability to publish a service content, resulting in the existence of malicious node manipulation routing. Obviously, because this approach can require nodes to expose their interest to the network, so it can introduce privacy challenges. If a third party is able to map identifiers to possible common content items, it may cause serious damage to the user's privacy. In addition, there are other routing-related security issues that have not yet been fully explored

3.1 Caching Technology

The present situation and characteristics of caching schemes made new challenges, such as, no center, self-organized, name-centric routing, multi-path transmission and in-network caching. In [10], the NDN (aka CCN) is introduced to improve the validity and efficiency of MANET, and it is shown that NDN is a new research direction of ad hoc network. However, the basic caching algorithm used in this article, and through the content stored in the CCN to cache all the content passed. If this design function was used in MANETs, it will bring too much duplicate content to the network.

In order to reduce the redundancy of contents in networks, Zeng introduced a parameter, data interval, in DatP [13]. The value at which the node holding the content sends data is set to the data interval, which determines the cache interval of the data forwarding path. When the DatP is forwarded by the intermediate node, the value of the data interval is decremented by one. If the data interval is equal to 0, the contents are cached in the node's content store and the data interval is reset. If the data interval is not 0, the DatP will be relayed immediately. Experiments show that the network with cache design can improve the performance, and the performance of the proposed cache strategy is always superior to the traditional Ad-hoc On-demand distance vector (AODV).

Different from the above research, the literature [14] mainly focused on how to improve the performance of content replacement, and through the use of named data to provide maximum content delivery information, and proposed a cache replacement strategy, the strategy can not only identify the content popularity and also consider the overlap of information, more suitable for MANET.

3.2 Routing Technology

A single physical node usually holds a complete data object, and the cache typically retains only some data objects. Based on Listen First & Broadcast Later (LFBL), a non-topology-independent data center forwarding protocol for wireless ad hoc networks is proposed [15]. Where the consumer decides the flood content request and the intermediate node eavesdropping the packet to find out if they qualify for the transponder. The receiver maintains the minimum state quantity in each node to perform all forwarding decisions. In order to avoid collisions, the data exchange phase should follow the distance-based forwarding rules. Experimental results show that LFBL is superior to AODV protocol in highly dynamic environment.

The NAIF is an NDM forwarding protocol [16], which aims to reduce the high overhead of CCMANET routing design. In general, NAIF and NDNF are compatible with all relevant relays, while LFBL implicitly selects the path between the consumer and the data holder. By evaluating the performance of NAIF as well as the existing CCMANET routing mechanism for NDNF and LFBL. Experiments show that in the multi-consumer data retrieval program, NDNF and NAIF completion rate higher than LFBL 30–60%. In both simulation and simulation, both NDNF and NAIF can reduce bandwidth usage by as much as 54%, keep the average response time and completion time close. Thus, NAIF can reload the data service as a starting point based on the name forwarding method and design reliable naming data MANET.

Although above mentioned researchers have proposed different routing technologies for MANETs, seldom system exploits them. Therefore, Yao et al. have implemented a wireless ad-hoc content-centric network over smartphone and proposed a loop-free name-based routing protocol [8]. Several smartphones are connected through free Wi-Fi interface, and share their video and Inter-net resources. Data are exchanged by name, not by IP again. The experimental results demonstrated that the wireless ad-hoc content-centric network performs better than IP-based protocol, and is very suitable in wire-less ad-hoc networks.

3.3 Mobility Management Technology

The mobility of the source node (SN) and the mobility of the client node (CN) are two mobile types of CCMANET. For static grid topologies, Alfano and Garetto have set up an ad-hoc networks with asymptotic delay-throughput trade-off based on content-centric scenarios [17]. Experiments show that the mobility of the system often leads to the decline of system performance, and the content of the characteristics of the popularity of the system performance has an important impact.

3.3.1 The Source Node (SN) Mobility

The SN mobility has brought many problems, such as frequent routing updates and low routing aggregation. In other words, the speed of the routing of all related content routers is very slow due to the mobility of the content source. In order to decrease the adverse effect on the system performance from the SN mobility, [18] proposed a mobility management scheme based on a partially extended route update method. In the CCN environment, this method is used in mobile consumer devices with content data, which can reduce the number of routing table entries and network convergence time. The operation of the partial path expansion (PPx) scheme consists of three steps: movement indication, path extension and path update & revocation.

3.3.2 The Client Node (CN) Mobility

The CN mobility led to the DatPs cannot be relayed to the CN since the SN or other intermediate nodes have no idea about the movement of the CN. To receive the content, the CN has to send the Interest again from the new location. This incurs huge control overhead for the network and delay experienced by the CN as the Interests need to be retransmitted again every time the CN changes its location. To solve the problem, there have been few schemes such as the Proxy-based mobility management [19], flow mobility management architecture [20], tunnel-based routing architecture [21] and architectures for solving the mobility issues in mobile ad-hoc networks for smart phones [20] and in the emergency networks [11].

In the proxy-based scheme [19], a fixed physical proxy is configured as an overlay architecture over IP networks. This scheme maintains the overall working of CCN limited between mobile nodes and physical proxies while the communication between the proxies is carried out using the normal Internet architecture. In [20], the flow mobility management architecture on Proxy Mobile Internet Protocol (PMIPv6) has been proposed. The architecture used physical mapping agent to solve the CN mobility issue. This scheme is cost inefficient like proxy-based scheme with regard to extra physical mapping agents and could also have some memory issues. Tunnel based routing scheme [21] outperforms the basic CCN in terms of control overhead, hit ratio and content delivery time. This scheme tunnels the interest and data between the old and new CN location. This scheme has triangular routing issues which have not been catered yet.

3.4 Security Technology

Currently, existing security schemes [22] have been considered inefficient, unavailable, and difficult to deploy, such as in public key encryption, PKI, and mobile application scenarios. In particular, PKI services are not available in applications where there is no infrastructure for in-vehicle networks. So CCMANET requires a more practical and flexible mechanism, and can verify the relationship between the public-key binding and the identity of the user.

In [23], the SECON of introducing CR and CRS was established. The function of CRS includes not only support the content cache, intentional resolution and forwarding of content-centric networks, but also supports descriptions of metadata from different data patterns, translations, and other interesting names that CRS can't perform. In SECON, users provide content-centric security solutions by using peer-to-peer exchange of information. Where the data owners can share encrypted published data items with others without having to predict which potential users are interested. And the proposed architecture supports several features, including secure intentional naming of messages, content announcements, and retrieval.

In [24], a security scheme based on social networks is proposed, which is used to solve the problem of the authenticity and integrity of network applications centered on mobile information. In a reliable social network, it allows the requester to verify the identity of the content creator and the public-key binding relationship through identity binding retrieval. The program has been validated on small-scale artificial networks and has demonstrated scalability in large real life social networks.

4 Challenges and Open Questions

Because of the limited space of the article, some important topics such as naming rules, name look up and CCMANET applications. Related reference may be made to other relevant literature, e.g. [25].

At present, there are still some challenges and open issues in achieving reliable and efficient content sharing for CCMANET, such as the following aspects.

- Topology control. The dynamically changing topology is one of the most significant features of MANET, which has an important impact on the performance of the network. But there is no relevant public coverage for the relationship between topologies and CCMANET performance. Therefore, there is an urgent need to study the impact of topology on CCMANET performance and design topology control mechanisms to optimize network performance.

- Joint caching and routing. Usually, caching and routing are designed independently, because caching primarily decides whether to cache resources, and routing is primarily improved by improving the network performance based on the identified resources and replicas. However, there are two aspects of the inevitable coupling. For example, under different caching algorithms, the same routing algorithm may show significant differences, and vice versa. In addition, in the future, the integrated design of multipath routing and co-caching is a challenging issue in CCMANET.
- True opportunities and economy models. It is important that the economic and engineering benefits of traditional MANET were quantified using CCN. In addition, the need to develop the underlying network economic model to meet the business community on the CCMANET comfort needs.

5 Conclusion

At present, the study of CCMANET field shows explosive growth, this article is difficult to cover all related issues. Therefore, in this paper, we have a systematic summary of CCMANET, and focus on the basic principles, new features, key technologies and remaining challenges. This will provide a complete understanding of CCMANET for researchers and practitioners.

Acknowledgements. This work was supported by the Foundation for National Key R&D Program of China plan under Grant 2016YFC0801800.

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