Issues and Challenges surrounding Wireless Multi-hop Ad-hoc Networks:Opportunistic Networks

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ABSTRACT

Wireless Multi-hop Ad-hoc networks have received increasing attention in the past years. The reason behind is due to their broad applications in various areas and easy deployment at low cost. Opportunistic networks are one of the challenging networks where network connectivity is temporary not permanent. In these networks performance of link is highly variable. These networks are very challenging mobile ad-hoc wireless networks and are characterized by frequent disconnections and partitioning. A complete path from source to destination does not exist for most of the time in opportunistic network. Due to this, the path is not stable and may change or break quickly. Therefore, in order to make communication possible in opportunistic network, the intermediate nodes may take care of data by storing data during the black out and forward it to other nodes when the connectivity resumes. Opportunistic networks introduce and presents several research challenges in all aspects of computing, networking, and communication technologies. In this paper, we outline our vision of opportunistic networking research. This paper discusses the characteristics, various research challenges, application scenarios in category of wireless multi-hop ad-hoc networks i.e. in opportunistic network. It also presents an insight into research in the area of opportunistic network.

Keywords
Wireless Network, DTN, Multi-Hop, Mobile Devices.

1. INTRODUCTION

The advancements in communication and networking technologies helps wireless networks to support ubiquitous computing vision that is supporting network access anywhere and at any time. Among various types of wireless networks, multi-hop wireless networks have been attracting increasing attention now a days due to its broad civilian and military applications. The infrastructure based connectivity of network is not always preferable because in some cases it is expensive to accommodate all devices with sufficient bandwidth in a cellular network or to deploy sufficient number of access points to cover all the devices. Therefore need arises of an self organized network which does not require any fixed infrastructure and which can scale well in case there is increase in the number of mobile nodes in the network. Due to limited transmission range of radio, many pairs of nodes in multi-hop wireless networks may not be able to communicate directly, hence they need intermediate node to forward packets. The Opportunistic network is one of the evolutions of wireless multi-hop ad-hoc network [1, 2]. These networks emerged as a new type of networking paradigm where communication between the source and destination happens on the fly and depends on the availability of communication links. In opportunistic networks, there is no end-to-end connectivity within nodes, the connectivity is intermittent and mobile nodes communicate with each other even if a route connecting them did not previously exist. In this type of network, it is not mandatory to have a priori knowledge about the topology of network. The network is formed opportunistically based on proximity and network availability, as well as by randomly connecting and disconnecting the networks and devices [3]. Due to wide availability of pervasive mobile devices as well as advancements in wireless networking technologies, the opportunistic network applications are promising networking and communication technologies for a variety of future mobile applications.

In opportunistic networks, mobile nodes transmit messages by exploiting the direct contacts, without the need of an end-to-end connectivity. Normally in these networks the number of participating nodes quickly discontinue their use of services in one area due to mobility. So, the rate of disconnection is very high in opportunistic networks [4]. There is not any requirement of strong connectivity in opportunistic communication. In these networks, mobility is the key to allow communication. For example, consider two disconnected static nodes, where communication between them is provided by a device that, due to mobility, sometimes is in range of one and sometimes of the other [5]. Thus the mobility of the node makes the communication opportunities. The transmission of data is achieved through the forwarding opportunities between nodes. The store-carry-mechanism is used by opportunistic networks which allow the mobile nodes to operate messages in different portions of network. In opportunistic

network, each node can act either as host or as a intermediate node, thus, it can store, carry and forward the message between other nodes [6].

Opportunistic network is a type of delay tolerant and intermittently connected network using an ad-hoc like structure. Opportunistic networking is used in many emerging applications, for examples wireless sensor networks, underwater sensor networks, transportation networks, pocket switched networks, and people networks. There always remains the need and desire to develop effective communication schemes that can better accommodate and utilize the characteristics of opportunistic networks [7]. By examining the basic properties and characteristics of opportunistic networks one can better design effective routing protocols and explore its applications.

The nodes in opportunistic network are normally out of the infrastructure coverage. All kinds of devices that are used in these networks have the communication capabilities embedded and several objects in a certain environment facilitate to create a communication network [8]. The communication network comprise of numerous network elements of the infrastructure and terminals/devices potentially organized in an infrastructure-less manner.

The opportunistic network exists temporally that is for the time-period necessary to support particular network services and accommodate new future enabled applications, requested in a specific location and time. There is need of dynamic and efficient mechanisms for creation of opportunistic networks. Fig. 1 shows that opportunistic network as a part of Cognitive control network and it is proposed by ETSI [9]. The CCN involves an emerging group of functionalities, whose aim is to introduce cognition mechanism to the evolving wireless world. The opportunistic network creation can be seen as a mean to provide extended coverage to the infrastructure.

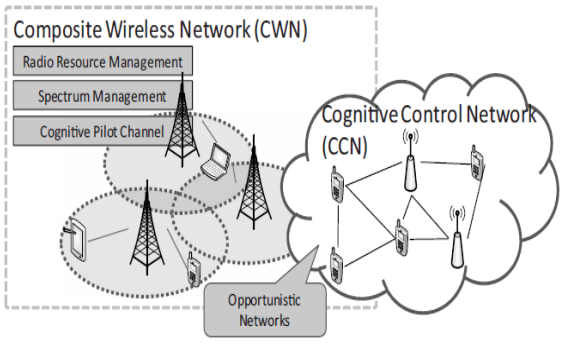

Fig. 1 Opportunistic Network

The largest focus of the research in opportunistic networks has been on routing [10], but other areas such as power awareness, quality of service [11], scalability, security and privacy, limited buffer capacities, jamming etc. must also be addressed. In this paper, we outline our vision of opportunistic networking research. The next Section describes the basics of opportunistic network operation. Section 3 describes various issues and challenges of opportunistic networking. Section 4 discusses various application scenarios for use of opportunistic networks. Finally, section 5 concludes the paper and discusses the future scope.

2. OPPORTUNISTIC NETWORK

The Opportunistic Networks differ from the traditional networks. In opportunistic network, a network is typically separated into several network partitions called regions. Due to which, a complete path or an end-to-end path between source and destination rarely exist. Mobile nodes are having the ability to discover each other and communicate by using all kinds of communication media including Bluetooth, WiFi, cellular based technologies [12] etc. Also if any path found then it may last for an unpredictable period of time. In this type of environment, the traditional applications are not suitable. They normally assume that the end-to-end connection must exist from the source to destination in order to make communication possible.

The opportunistic network enables the devices in different regions to interconnect by operating message in a store-carry-forward fashion. The intermediate nodes implement the store-carry-forward message switching mechanism by overlaying a new protocol layer [13], called the bundle layer, on top of heterogeneous region-specific lower layers, as shown in Fig. 2. In opportunistic network, each node act as an entity with a bundle layer functionality. Due to this each node can act either as a host, a router or a gateway. The task of bundle layer is to store, carry and forward the entire bundles (or bundle fragments) in-between the nodes in the same region [23]. On the other hand, the messages are transferred across different regions through bundle layer of gateway. To forward bundles between two or more regions the gateway must have persistent storage and support for data forwarding [23]. The responsibility for storing, carrying and forwarding data in opportunistic network is of bundle layer.

A. TYPES OF OPPORTUNISTIC NETWORK

The network must adapt itself according to users need and behaviour. This desire is the motivation behind opportunistic networking concept which allows users to move from a network of devices in-between. From practical point of view, this can be viewed as a real evolution of the general class of MANET concept. Opportunistic networks are self-organized mobile wireless multi-hop ad-hoc networks that opportunistically use all kinds of communication possibilities which wired or

wireless devices can offer. In the current research trends, one can distinguish three major types of opportunistic networks [14]:

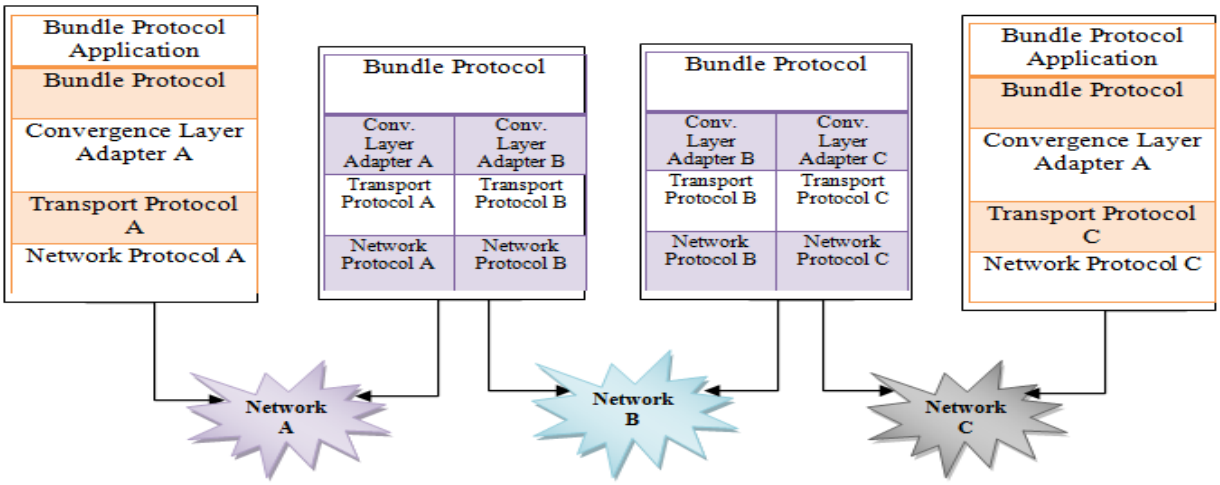

Fig. 2 Protocol stack of opportunistic networks corresponds to DTN

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- *Opportunistic Communication Networks:* These networks belong to is class 1 Opportunistic Networks. The only goal of these networks is to enable, on the fly, the establishment of connections and communications among previously disconnected nodes.

- *Opportunistic Data Dissemination Networks:* These networks belong to class 1.5 Opportunistic Networks. These networks opportunistically propagate and forward data.

- *Opportunistic Capability Utilization Networks* (OCUNs): These networks belong to class 2 Opportunistic Networks. This is a more generic class in the sense that its role encompasses communication and data dissemination and includes such other capabilities as resource management, services discovery, and management, etc.

In order to accomplish the network's goal, the first class promotes the idea that the network architecture can grow or shrink opportunistically by discovering, analyzing, inviting, or integrating/releasing new available pervasive resources [14]. The second class has recently attracted a lot of interest due to their suitability for opportunistic networking applications and it is also called a network of regional networks. Two subclasses of class 2 opportunistic networks are oppnets and delay/disruption tolerant networks. Examples of DTNs are pervasive networks made of user's devices only, socio-aware community network, wildlife tracking sensor networks and so on.

B. FEATURES OF OPPORTUNISTIC NETWORKS

The opportunistic networks and their salient features can be characterized as follows [15].

- In opportunistic network whenever nodes move away or switch off their power to save energy, links may break or shut down [12]. Due to this there is an intermittent connectivity and network partition occurs. As a result, now the nodes communicate with each other via opportunistic contacts through store-carry-forward mechanism. If there is no consistent and reliable complete path between the source and destination then other protocols are required. In this case the end-to-end communication using the TCP/IP protocols does not work.
- An opportunistic network is a network of wirelessly connected nodes. Communication range between two nodes is not further than walking distance. In this type of network nodes are connected temporarily. So the network must provide node discovery i.e. able to discover other network nodes for message forwarding. In context of opportunistic networks the contact opportunity, node storage and node cooperation aspects are of particular importance in determining the strength of opportunistic network.
- The opportunistic networks have high error rates. Ambiguous mobility patterns; unlike the case with public bus services that maintain fixed routes or planetary trajectories, future behavior of a node is not fully known for many opportunistic network applications.

- There is long propagation delay between nodes, in addition to variable queuing delays at node buffers in opportunistic networks. This all creates an end-to-end path delays that far exceed the threshold levels usually tolerated by Internet protocols and applications that usually rely on quick return of active acknowledgments.

In order to characterize the system behavior, following metrics can be introduced i.e. the contact time, Inter-Contact time, first contact time, node degree, network diameter, travel length, travel time, effective travel time etc. [16].

3. RESEARCH ISSUES AND CHALLENGES

One of the basic research issue and fundamental challenge to communication and various information technologies is to provide dependable and reliable communication in emergency situations. In this section, we describe some specific challenges and research issues in opportunistic network. These are mainly contact opportunity, link discovery, buffering, data forwarding and routing, security and privacy. All these are described below. When we are talking about designing of opportunistic networking system we must take care of the research issues like node mobility, coordination between nodes, data collection and delivery, power management and memory management etc.

- *Contact Opportunity:* It basically refers to make contact to nearby node which may seem closer to destination. The wireless domain is inherently dynamic and due to mobility of node, a node might make contact with other nodes at an unpredicted time. Since the contacts between nodes are not easy to predict, they must be exploited opportunistically for exchanging messages between nodes that can move between remote fragments of the network [12]. An *arising communication opportunity*, when talking about opportunistic networks, does not refer to an end-to-end or complete path between the source node and the destination node of a message. Rather, it may simply refer to the possibility to transmit to an intermediate node which is nearer to the destination node with respect to the source node. Transmissions are thus managed in a hop-by-hop fashion. Reference [17] define two parameters, contact duration and inter-contact time that are important parameters of interest in determining the strength of opportunistic network.

- *Link Discovery:* In this the mobile devices advertised their identity, capabilities and find out its corresponding neighboring nodes in its vicinity. Since the wireless channel is highly dynamic so link discovery is also a challenging task.

- *Storage constraint (Buffering):* In this the intermediate nodes requires to have enough storage to store all messages for an unpredictable period of time until next contact opportunity occurs so as to avoid dropping packets. This results an increase in the required storage space (buffer) as a function of the number of messages in the network. The storage duration in opportunistic networking is typically longer than in traditional routing approaches because nodes have to wait for a communication opportunity to occur. The mobility of nodes helps create communication opportunities and reduce the storage duration and the end-to-end delay of transmissions. Therefore, the research on routing and forwarding strategies must take the storage constraints into consideration and it is also a challenging task.

- *Data Forwarding and Routing*: The reason for failure of end-to-end connectivity is high-mobility which results in fast route breakage. Such failure is caused by the mismatch between route breakage time and route adaptation time. Due to this mismatch the establishment of a new route takes longer time as compared to breakage of route. In a highly mobile opportunistic network, a node potentially may have one or more connected neighboring nodes that can lead to the destination of the broken route all the time [19]. So design of efficient routing scheme in such scenario is a challenging task.

- *Security and Privacy*: When devices join the network, the authentication cannot be performed instantly. This takes time. This may be the one of the sources of privacy and security. We cannot guarantee in a network that malicious devices will not join. As well as when any device join the network we cannot rate them as malicious until they show their notorious behavior. The distribution of secret keys securely to all non-malicious devices is very difficult in such an environment. Hence, relying only on cryptography-based authentication mechanisms will not help in all situations. The security and privacy [20] challenges for opportunistic networks can be listed as follows:

- By increasing trust among devices
- To provide secure routing
- To protect data privacy
- To ensure data integrity
- To identify dangerous attacks and provide their solutions

The opportunistic networks are highly heterogeneous due to which the solutions proposed for secure routing

protocols in wireless ad-hoc networks or the Internet cannot be used directly in opportunistic networks. Their nodes have different processing abilities, power sources, modes of transmission (wired or wireless), etc. The proposed approaches—e.g., IPSec, WEP—use mostly cryptographic solutions to minimize the probability and effects of possible attacks [21].

4. APPLICATION SCENARIOS

One of the example of opportunistic networking that creates an environment for communication is when two or more users carrying mobile devices that are wireless enabled (e.g. Bluetooth, Wi-Fi) meet each other or walk pass by at some popular places and then try to exchange data among them. The other scenario where opportunistic networking could be useful is in the rural areas in developing countries which have intermittent connectivity to fixed infrastructures or no connectivity at all and the cost factors involved in establishing fixed infrastructures are not economically feasible or impossible [21]. In such scenario the opportunistic networks are an affordable solution. The applications of opportunistic networks are in all kinds of emergency situations—including man-made and natural disasters. We have seen great disasters in the past years, such as 9/11 terrorist attack, tsunami in the Southeast Asia etc. These disasters caused too much casualties and damages and lot of problems were faced in relief operations by relief workers. There is a common threat to all these problems: inadequate communication facilities in the disaster areas. The researchers are also trying to implement a number of real application scenarios upon opportunistic networks. In some applications it is not possible or advisable to provide more structured network. One of the examples of this case is wildlife tracking application whose aim is to monitor wild species in unmanned scenario because in these systems it is important to limit human intervention to respect the natural ecosystem. It focuses on tracking feral species to deeply investigate their behavior and understand their interactions [22]. Wildlife monitoring is done using special tags with sensing capacity that is to be carried by the animals under study. Base stations that may be fixed or mobile are deployed at some place. In both cases data collection from all the deployed tags is quite challenging. Therefore the data is collected by exploiting pair-wise contacts between the animals to let them exchange the information already collected. As a result, each animal eventually carries the information collected by its own together with the information collected by the animals it has encountered [23]. Some of the examples of opportunistic networks that can be taken as reference network scenarios are dancing room, conference room, mountain area, city centre etc.

- Dancing room: People equipped with small communication devices, likely using short-range technologies such as Bluetooth. People will exchange short data files, video clips, and images, but they may also need to send broadcast messages, such as requests for car pool services.

- Conference room: People attending a conference or a business meeting, each of them equipped with one or more communication devices. In this case, users are either stationary or moving at walking speed. Traffic will be mainly represented by data file and video contents.

- Mountain area: There are various major winter sports activities like winter hiking and mountaineering etc. that are attracting a large number of people. Many different social clusters of people may traverse it at any point in time (e.g. tour groups, alpine guards, alpine skiers etc). In this case the opportunistic networks work as socio-aware networks.

- City Centre: Urban centres, where both vehicles and people equipped with communication devices exchange information and ask for services, will be soon a reality in several countries. Possible services include taxi reservation, request for information on fast routes, events or point of interest.

5. CONCLUSION AND FUTURE SCOPE

Opportunistic networking is an emerging system now-a-days that is rapidly growing interest in the field of networking research. The research in this field can still be considered in its infancy state. The opportunistic network places different research challenges at each of the layer as well as its applications expose ideas like exploitation of user's vicinity, autonomous dissemination of information, open and unrelated user group etc. These networks can govern the future communication networks but still there are some technical challenges that are to be focused and solved. This paper provides a quick overview and discusses various research challenges in opportunistic networks. In short, we had provided some details on architecture in terms of protocol stack, characteristics, challenges and issues of opportunistic networks and various applications scenarios. One can pursue research in any one of these challenges presented in this paper. Every area is vast enough to better explore more about opportunistic networks.

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