A Study of Named Data Networking as Communication Protocol for Multi-hop Wireless Ad Hoc Network

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Abstract. Named Data Networking (NDN) has been repeatedly quoted in numerous past and existing literature reviews to have replaced Host Centric Networking (HCN) due to its ability to solve energy efficiency issues inherent in Multi-hop Wireless Ad-hoc Networks (WAHN). However, this claim is proven to be wholly unsubstantiated and is not justified by academic proof in said articles. Therefore, this study take the initiative to fill in this gap by presenting a comparative study of NDN based MWAHN and HCN based MWAHN through the use of real implementation by measuring two parameter metric that are related to energy efficiency, namely energy consumption and file transfer completion time. For this study, NDN-based MWAHN is compared with two type of actively developed HCN routing protocol implementation, namely Babeld and BMX6. The results obtained from this experiment is crucial for MWAHN researchers to gain better understanding of the real potential of the NDN based routing that can be used as a solution for energy consumption issues that exist in wireless multi-hop ad-hoc network.

1. Introduction

Energy is a limited resource on any mobile node in a Multi-hop Wireless Ad-Hoc Network (MWAHN) because the energy source is derived solely from the battery, which in turn can only store limited amounts of energy, to operate mobile devices even if it is not connected to a fixed power supply like a mesh router in a wireless mesh network. Furthermore, the mobile device in a MWAHN not only serves as a consumer, but also as a router or relay to network traffic from other mobile devices to form a multi-hop wireless network [1-5]. Therefore, energy conservation in a MWAHN is of critical importance and needs to be addressed effectively, as the lifespan of a mobile device in a MWAHN must be as prolonged as possible. This is because the lifespan of mobile devices in a MWAHN directly influences the lifespan of the network itself [6-9].

Hundreds, even thousands of literature that has been published since decades ago until now concerning the ideas and suggestions to reduce overall energy consumption in MWAHN to enhance
energy efficiency in MWAHN implementation. However, up to now we still do not see the use of MWAHN technology widely in the real world as energy conservation issues in MWAHN is still ineffectively solved [10]. Some researchers argue that the use of host centric networking technology which form the basis of MWAHN technology is the main factor that cause high energy consumption in MWAHN though many energy efficiency improvement methods have been proposed [11-14]. Over the years, research on MWAHN is still bound to the host centric networking, especially TCP/IP since the beginning of MWAHN, though MWAHN requirements are inconsistent with what TCP/IP can provide.

Host centric paradigm in TCP/IP requires a guaranteed link session between the source and destination. The mechanism has no trouble in the fixed network such as the Internet, but it was a massive challenge to provide a guaranteed link session for node to node communication in MWAHN because network topology in MWAHN is dynamic in nature and very unstable. TCP/IP network or host-centric paradigm has been proved to be effective for nearly five decades for the used in the Internet. However, until today the host centric networking has also been proved to be ineffective in supporting the development of MWAHN that can be applied not only in limited sectors such as military and emergency task force but also in the civilian sector [10, 12-16].

To cope with that situation, a decade ago, Van Jacobson and PARC (Paolo Alto Research Center), XEROX initiated an effort to establish a new technology called Content Centric Networking to replace TCP/IP as the de facto protocol for the Internet to overcome the current problems, in which the trends for Internet utilization has evolved from a destination point to point communication to delivery and sharing content such as video streaming, VoIP and peer to peer file sharing such as bittorrent. this evolution has caused the host centric networking such as TCP/IP to be inefficient for the current needs of the Internet [17, 18].

University of California, Los Angeles with several other academic bodies have follow up the efforts by establishing the Named Data Networking (NDN) Consortium to carry out research and development of the same ideas and philosophy under the label of the Named Data Networking (NDN). In the early stages, NDN only use CCN implementation called CCNx for their research. But in 2013, they decided to create a fork against CCNx source code to develop their own NDN implementation because the focus and direction of their research varies with CCN, although they shared the same philosophy and basic architecture. Until 2014, NDN Consortium decided to create NDN Next Phase (NDN-NP) as the basis for the development of NDN implementation from scratch NDN in order to create a more modular and easier to use NDN implementation for research purposes and to produce a new and better design features [19, 20].

However, despite copious literature stating that a NDN based MWAHN is more energy efficient than a host-centric MWAHN [10, 13, 15, 21-24] - there has conspicuously been no further investigation comparing the energy efficiency of existing host-centric implementation versus a NDN MWAHN based implementation, either in running simulations or testbed. In this regards, this paper can be considered as the first towards filling this gap.

2. Related Work
There are some disadvantages of simulation compared to the use of testbed for wireless networks such as Wi-Fi. Of exposure obtained by the [25], Wi-Fi range is variable compared assumption in network simulator where Wi-Fi range is constant. Transmission range and carrier sensing range is constantly changing even within the same session testbed. In addition, the Wi-Fi signal range is also influenced directly to the data rate at which the Wi-Fi signal range will decrease if the data rate increases. Changes to Wi-Fi signal range is also influenced by other factors such as the weather, the type of data transmitted, interference, etc. [7].

When we want to design a testbed to meet the needs of our experiment, to the best of our knowledge, no previous research can be used as reference on how the testbed method is used to test the mobile device energy consumption in multi-hop wireless ad-hoc network. Thus, we obtained the references on testbed method of the mobile device itself (not related to the multi-hop wireless network) as well as previous studies which worked on energy consumption in wireless sensor network
Among the previous research that we use as references are by [27-29], who examine how energy consumption of mobile device were obtained through testbed method. From there, we learned that most of the previous research that were related to energy consumption study of mobile device used Monsoon Power Monitor—where it can be used as energy and power supply profiling tools for mobile device to emulate battery power source.

This experiment uses the implementation of routing protocol that can be publicly acquired to compare between NDN-based routing protocol and HCN-based routing protocol from the energy consumption perspective. We chose the go-ndn forwarder to provide an alternative to official NDN implementation. go-ndn used go language as programming language for NDN implementation, thus we believe that it is more efficient, easier and faster than official NDN platform which uses C++, Java, and Python. For comparison of Host Centric Networking, we have choose two existing open source mesh routing implementation that is widely used in the mesh network community i.e. Babel and BMX6.

3. Testbed Setup
Testbed for this work is carried out on each multi-hop routing protocol as much as 30 times to allow the size of the sample from the testbed result analysed statistically. Prior to the statistical analysis test, normality and homogeneity test done beforehand to ensure the type of hypothesis tests and appropriate post hoc. If the data is not normal, the new data will be taken to replace the extreme data. This is because, based on our observations, extreme value data is influenced by external factors such as the hardware issues like over-heated and Wi-Fi driver.

3.1. Testbed Setup
The experiments are a preliminary study to examine the potential use of NDN as a communication protocol for MANET in improving the energy efficiency of MANET. For a start, NDN based MANET approach is compared to two existing HCN based MANET solutions namely Babeld (implementation of Babel routing protocol) and BMX6 (implementation of BMX version 6 routing protocol). Testbed setup does not involve node mobility as it focuses more on the energy consumption of dynamic routing solution in multi-hop wireless ad-hoc network environment.

![Network topology of Testbed](image)

**Figure 1.** Network topology of Testbed

The network topology shown in Figure 1 is used in this experiment to ensure that all network traffic in the wireless multi-hop ad-hoc network is created via node 4. This is because the energy consumption of mobile device is only done on node 4 using the Monsoon Power Monitor (see Figure 2).
Figure 2. Energy Consumption Measurement Using Monsoon Power Monitor

Energy consumption of mobile device is taken externally using the Monsoon Power Monitor to ensure that the energy consumption data gathering process does not interfere with the readings of the energy consumption itself if taken internally. Another reason for using Monsoon Power Monitor is due to accuracy of energy consumption data obtained and power consumption data can also be used for power consumption profiling purposes for the next phase of this research.

Multiple consumer and single provider scenario or simply called multicast scenario is used in this preliminary experiment as shown in Figure 3. Multicast scenario was chosen because the advantages of NDN architecture can be seen especially at intermediate nodes if more than one consumer nodes retrieve the same content from the same content provider compared to HCN. Therefore, this experiment able to observe the advantage of NDN in multicast scenario compared to HCN as communication protocol can reduce energy consumption of mobile device especially intermediate node when content retrieval is performed.

Figure 3. Experiment Scenario. Single Content, Single Producer, Multiple Consumer
Figure 4. Banana Pro Single Board Computer (SBC)

Banana Pro Single Board Computer (SBC) was chosen instead of smartphone to represent a mobile device as it has a variety of input/output terminal options for communication purposes either via ethernet or serial. Although the Banana Pro SBC has the same main component as the smartphone, the Banana Pro SBC also has no necessary component for MANET testbed purposes such as LCD display, GSM chip, various sensors and camera. In addition, the cost of the Banana Pro SBC is significantly lower than the smartphone. Banana Pro is also easier to customize and operate for experimental purposes compared to smartphones which are more suitable for use as a consumer product rather than for MANET experimental purposes.

4. Result

Comparison was made between NDN based MANET solution, Babeld and BMX6 to obtain energy consumption of intermediate node (Node 4) and average of file transfer completion time when transaction file was performed in multicast scenario.

The results obtained from the experiments performed can be seen in Table 1. Energy consumption of Node 4 is calculated in joule units. While file transfer completion time refers to the average of completion time for all three consumer nodes namely Nodes 5, 6 and 7.

| Dynamic Solution | Routing | Energy Consumption (Joules) | File Transfer Completion Time (minutes: seconds) |
|------------------|---------|-----------------------------|-----------------------------------------------|
| NDN              |         | 104.20                      | 01:13.31                                      |
| Babel            |         | 274.50                      | 03:05.27                                      |
| BMX6             |         | 231.13                      | 02:32.83                                      |

The use of performance metric file transfer completion time as an additional measure is to show that the lowest energy consuming solution does not necessarily sacrifice performance of network transaction in MANET environment.

Visually, Figure 5 shows the significant difference in energy consumption of Node 4 when using the NDN based MANET solution compared to when using Babeld and BMX6. File transfers when using NDN based MANET consumed 104.20 joules compared to when using Babeld of 274.50 joules and BMX6 of 231.13 joules.
At the same time, in terms of performance, the use of NDN based MANET is also better than Babeld and BMX6. This is because the completion time of file transfer transaction when using NDN based MANET is 1 minute 13.31 seconds compared to Babeld which is about 3 minutes 5.75 seconds and BMX6 which is 2 minutes 32.83 seconds (refer Figure 6).

NDN based MANET gives better results than Babeld and BMX6 because in the multicast scenario, Node 4 only gets one copy from content provider (Node 1) for different content consumers. At the same time, only two copies were sent by Node 4 to two consumer nodes namely Node 6 and
Node 7. Meanwhile, Node 5 received copies of content from Node 6 and Node 7. NDN's approach to content distribution proved to be more energy efficient than HCN represented by Babeld and BMX6.

5. Conclusion and Future Work

Results obtained from this experiment is the beginning for us to understand the real potential of the NDN based routing to be used as a solution to the issue of energy consumption in multi-hop wireless ad-hoc network. In future works, we plan to see the comparison of the energy consumption of NDN based routing protocol with HCN based routing protocol when using different network traffic such as video on demand (VOD) and live streaming video with different nature and needs of the file transfer traffic. In addition, we also plan to see the advantages of NDN based video on demand (VOD) and live streaming video with different nature and needs of the file transfer network traffic. In addition, we also plan to see the advantages of NDN based routing protocol in terms of energy efficiency compared with HCN based routing protocol when it comes to mobility parameters and topology changes in the testbed.

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