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Multimedia Cross–Platform Content Distribution for Mobile Peer–to–Peer Networks using Network Coding

[Short Paper]

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ABSTRACT

This paper is looking into the possibility of multimedia content distribution over multiple mobile platforms forming wireless peer-to-peer networks. State of the art mobile networks are centralized and base station or access point oriented. Current developments break ground for device to device communication. In this paper we will introduce a mobile application that runs on Symbian as well as iPhone/iPod devices and is able to exchange multimedia content in a point to multipoint fashion. The mobile application coined PictureViewer can convey pictures from one source device to many neighboring devices using a wireless 802.11 network together with network coding and user cooperation. The advantage of network coding in this context is that the source devices only need a minimal amount of knowledge about the sinks received packets and therefore only a minimal amount of feedback is needed to ensure reliable data delivery.

Categories and Subject Descriptors

H.m [Information Systems Applications]: Miscellaneous;
D.2.13 [Software Engineering]: Reusable Software—*Reusable libraries*

General Terms

Experimentation

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Keywords

Reliable broadcast, network coding, cooperation, MANET, 802.11

1. INTRODUCTION

In recent years the amount of Mobile Ad hoc NETWORK (MANET) oriented applications has increased rapidly. This development is partly driven by the increasing spread of 802.11 capable mobile devices such as smart-phones, PDAs and tablets, but also by the increasing demand for ad hoc media and content sharing services e.g. for the class-room, conference and office. For these types of one-to-many services the traditional point-to-point data distribution paradigms provide a poor utilization of the available network resources. In both wired and wireless networks multicast provides a favorable solution, where data is sent along branches of a multicast tree and thus consuming a minimal amount of resources. Although IP multicast provide suitable delivery semantics for certain applications and services in small scale MANETs, it suffers from one major drawback namely the lack of reliable data delivery mechanisms, which is need for multimedia content distribution among mobile devices.

Reliable multicast is required by an increasing amount of services not only the content sharing services mentioned, but also in e.g. in military networks, car-to-car networks, including a wide range of one-to-many services used in the Internet today [6][1]. However, providing reliable data transport in MANETs poses several challenging problems due to the high mobility, unstable nature and typical resource constrained mobile devices e.g. in terms of energy, computational power, and memory. This is further complicated as the requirements posed by different reliable multicast applications typically cannot be supported by a single underlying protocol or single set of transport mechanisms. Different multicast applications have different characteristics and requirements e.g. in terms of, error-control, in-order delivery, delay sensitivity, support for multiple sources, scalability, impact on other traffic types, etc [6]. This differs from reliable unicast

protocols where the requirements remain reasonably general, allowing the delivery semantics of the Transmission Control Protocol (TCP) protocol to support a wide range of applications. This diversity in requirements has resulted in a variety of proposed reliable multicast protocols. Most proposals rely on two key approaches namely Automatic Repeat-reQuest (ARQ) in which a source retransmits lost packets and Forward Error Correction (FEC) in which the source transmits redundant parity bits allowing for error recovery at the sinks. Pure ARQ, suffers from the so-called feedback implosion-and exposure-problem [9]. Whereas pure FEC schemes cannot provide full reliability. To mitigate these issues Hybrid ARQ schemes combining ARQ and FEC have been proposed and investigated, and its performance is in general well understood [7]. Although traditional ARQ and FEC schemes have proved very useful in the construction of efficient reliable multicast schemes, recent results indicate that further improvements may be achieved for MANETs via the combination of two emerging technologies namely; Cooperative Wireless Networks (CWNs) and Network Coding (NC)[3][10].

Both Cooperative communication in wireless networks and Network Coding are new research areas which have generated a significant amount of interest in recent years[2]. CWNs breaks with the traditional client/server network structure to create a number of advantages for cooperating devices. Previous work has shown that CWN in some setups can be used to increase throughput, reduce delay, and reduce energy consumption for the cooperating nodes [2]. NC offers properties that support cooperative data distribution schemes by allowing re-coding of data flows at intermediate cooperating nodes, and thereby offering a higher flexibility and potential gains over traditional end-to-end codes. NC changes the current paradigm in switching computer networks often referred to as store-and-forward or routing. Traditionally in networks, flow of information has often been compared to flow of water in pipes or crates transported by trucks. This analogy is inadequate in NC as information flows are no longer considered as atomic entities but mixed at nodes in the network. This mixing has been shown in theory to exhibit several advantageous properties related to throughput, robustness, security, and complexity in communication networks [5]. In both areas a vast amount of the promising results have been verified through simulation and/or analysis, however issues arising from real implementations are still largely unexplored. In particular it remains unclear how the transport level protocols should be implemented and whether reliable multicast schemes in practice may benefit from network coding and cooperation.

2. NETWORK CODING AND COOPERATION

In this section we provide a short background introduction to the implementation of network coding and cooperation.

2.1 Network Coding

The basic operations of a network coding system is shown in Figure 1. In the following we assumed that a original file F is being encoded. To lower the complexity of the encoding and decoding operations the file is split into a number of chunks also called generations each consisting of g packets [4].

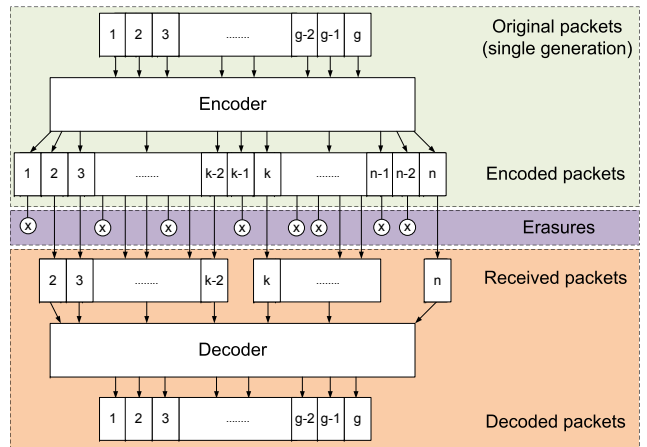


Figure 1: Encoder.

In Figure 1 the encoder is represented as the top layer. The encoder works by by creating and sending linear combinations of the original data, in this case generating n packets. The middle layer represents the wireless channel where packets are lost depending on the channel conditions. When packets are received at a node in the network they are passed to the decoder represented by the bottom layer in the figure. In Figure 1 the decoder receives k packets, and will with high probability be able to decode the original data as long as $g \leq k$. As shown by this example one of the main advantages of network coding over traditional packet routing is that the amount of knowledge required for a sink to send useful information has been reduced by a factor of F/g , or said in another way we only require knowledge about whether a generation is decoded or not. One additional operation not directly shown in the figure is recoding. Recoding is possible in network coding, and allows nodes other than the sink to send encoded packets. Recoding is implemented by allowing nodes to create new linear combinations of the content in their decoder. For a more in depth description and discussion of the implementation of network coding the reader is referred to [4].

2.2 Cooperation

Cooperation in wireless ad hoc networks has received an increasing amount of interest in recent years. An example scenario how this breaks from the state-of-art is shown in Figure 4.

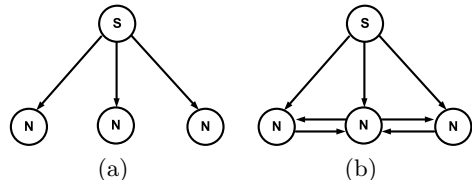


Figure 2: (a) Current network scenario, (b) network coding and cooperation scenario.

As shown in Figure 4 cooperation breaks from the traditional client/server communication pattern and allows neighbouring devices to communicate directly. This approach has

been shown to yield performance improvements in terms of both throughput and energy consumption. Further results and a thorough introduction to cooperation in wireless networks can be found in [2]. In this work direct user cooperation is used together with network coding to implement a reliable broadcast protocol.

3. PICTUREVIEWER APPLICATION

The pictureviewer application is a very simple application. The main focus is to demonstrate the feasibility of the proposed architecture. Even though the pictureviewer is focusing on distributing pictures from one to many devices, it is obvious that other multimedia types such as video or audio can be easily supported too. Nevertheless for the presented paper we limit the scope to pictures only. The main focus here is on the need of network coding and user cooperation.

One potential use scenario might be a group of people sitting together in the restaurant having dinner. If one person would like to show pictures from the last holiday trip to all other people, it might be hard to do this on a single mobile device. One solution is that the device with the current picture is passed from one person to another. That is not that much fun and will also take a lot of time. A pictureviewer application seems to be very useful for such a case. Using the app, the presenter can just go through the pictures and send all interesting pictures to the friends. Technically there are several alternatives. The simplest solution is to send the picture from the sending device to each listen device in a unicast fashion. That does not require that much technical knowledge. On the other side it will take time and also drain the battery of the involved devices. Another drawback is that the people will not see the pictures at the same time. Broadcasting is an option but requires a lot of signalling back to the originating device to ask for retransmission of missing or erroneous packets. For a large number of receiving devices that can take a while. Network coding helps to make the overall retransmission more effective as it requires less packets to send. Furthermore the user cooperation helps to perform the retransmission. As the device use network coding the user cooperation will be able to create valuable packets on the fly instead of just repeating known information for the cooperative cluster. All in all is the combination of user cooperation and network coding leading to the following advantages, firstly decreased time and energy to distribute the information among the interested devices compared to the standard approach. Secondly, more fair distribution of the energy spend to distribute the content, and thirdly coverage extension to devices that are not in range of the originating device.

Cross-platform support is an important issue if it comes to mobile peer-to-peer support. Even though currently most manufacturers try to close their systems by cutting out other vendors, there is a vital need to support cross platform. In this paper we focus on Nokia and Apple only, but it should be clear from now on that this is not limited to those two.

4. THE TESTBED

The testbed had two different setups. The first testbed setup was focusing on the single devices only. In Section 5 the individual coding speeds for different mobile platforms are presented. In the first testbed we are using four different platforms, namely one iPhone 3G, iPod Touch 2nd Gener-

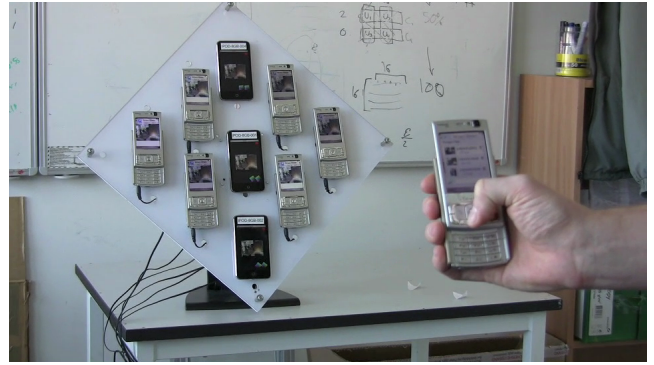


Figure 3: Receiving mobile device grid and one iPod touch and one Nokia N95 for transmitting.

ation, iPod Touch 3rd Generation and one Nokia N95. In Table 1 the technical details for each individual platform is given. All Apple products downclock the CPU clock rate. Nevertheless the iPod Touches have the most computational power followed by the iPhone and the Nokia N95. The network coding approach used here is based on Galois field sizes of 2. The advantages of this approach compared to larger field sizes has been proven in [4].

The second testbed comprises nine mobile devices as receivers and two mobile devices transmitting data as given in Figure 3. This testbed is to investigate the receiving speeds of the individual receivers due to different loss patterns. Furthermore this testbed is used for demonstration purposes as given in [8].

5. RESULTS

In this section the performance results of the individual coding speeds for the different platforms are shown. In Figure 4(b) and 4(a) the decoding and encoding speeds for the Nokia N95, the iPod Touches and the iPhone are given for different generation sizes, respectively. From the presented results we can draw the conclusion that the encoding as well as the decoding speed are sufficient to saturate the wireless throughput of an adhoc 802.11 network as we use generation sizes lower or equal than 256. The differences between the platform is a result of the inbuilt CPU. The iPod Touch 3G has the strongest CPU and yields therefore more than 35 MB/s using a generation size of 16. The Nokia N95, iPhone and iPod Touch 2G yield more or less the same results which are the half of the iPod Touch 3G.

For the decoding we see that the iPod Touch 3G yields up to 30 MB/s using a generation size of 16. The Nokia N95 and iPod Touch 2G yield more or less the same results even though the iPod has a stronger CPU. The iPhone is giving us the worst results in terms of coding speeds.

All in all show the results that the coding speeds on mobile devices are not the limiting factor anymore.

6. CONCLUSIONS

In this paper we have introduced a way to disseminate multimedia content within a mobile peer-to-peer system. We advocate that future mobile networks will change from centralized to decentralized and that multimedia content will not only come from centralized access points but may be also exchanged among mobile devices within close proximity. In

Table 1: Comparison of the important technical data of the different mobile devices under investigation.

mobile device	Processor	clock rate	memory
iPod Touch 3rd generation	ARM CORTEX-A8	833 → 600 MHz	256 MB DRAM
iPod Touch 2nd generation	ARM11	620 → 533 MHz	128 MB DRAM
iPhone 3G	Samsung 32-bit RISC ARM 1176JZ(F)-S	620 → 412 MHz	128 MB eDRAM
Nokia N95	ARM 11	332 MHz	18 MB

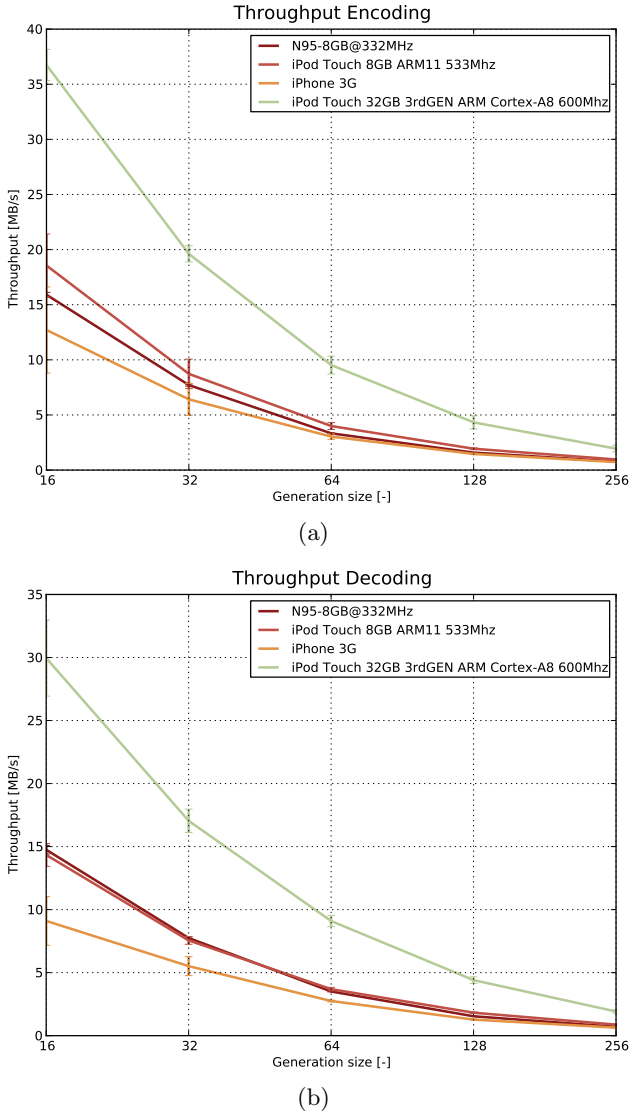


Figure 4: (a) Encoding speeds for Nokia N95, iPod Touch 2G/3G and the iPhone, (b) decoding speeds for Nokia N95, iPod Touch 2G/3G and the iPhone.

order to do the later, we propose to use network coding and user cooperation. A small application running on Nokia devices as well as on Apple devices has been presented to show the feasibility of this approach [8]. The application was focusing on picture delivery only, but without loss of generality this could be extended to other multimedia types as well. The paper has shown that the implementation on different platforms is feasible as well and coding rates higher

than the data rate that can be achieved on the wireless air interface has been presented. In [8] the full blown testbed with the pictureviewer application is shown.

7. ACKNOWLEDGMENTS

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