Choosing Multicast Configuration with Forward Error Correction for Mobile Multiaccess Heterogeneous Users

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***Abstract*—Mobile devices are typically equipped with multiple access network interfaces, supporting the coexistence of heterogeneous wireless access networks. The selection of an optimal set of multiple serving mobile networks for multicast streams is NP-hard and is, therefore, a challenging problem. We propose a simple heuristic approach that provides configuration of multicast groups for a given network topology and network conditions. We consider that a forward error correction technique is applied to deal with packet loss of the wireless communication.**

***Index Terms*—Wireless networking, mobile network selection, multicast, forward error correction.**

I. INTRODUCTION

Continuous development of various wireless network technologies, mobile devices and services lead to complex and highly dynamic networking and challenge resource limitations of wireless access networks. According to a recent forecast [1], global mobile data traffic grew 69 percent in 2014 reaching 2.5 exabytes per month at the end of 2014. Mobile video traffic exceeded 50 percent of total mobile data traffic for the first time in 2012. Global mobile devices and connections in 2014 grew to 7.4 billion, up from 6.9 billion in 2013. The report shows that video traffic will continue to dominate, and nearly three-fourths of the world's mobile data traffic will be video by 2019. It implies that we need intelligent mechanisms for optimized bandwidth management in multi-access wireless networks. These mechanisms should be capable of combining multicast transmissions with the usage of multiple connections and optimization of the multipath routing.

Another important concern is that channel conditions and packet loss in a specific wireless network can vary drastically for users of the same multicast transmission. It prompts applying different error-correcting parameters for different users in multicast.

Implementing multipath solutions for the multicast scenario in a multi-access network is not straight forward because the formulation of this solution is NP-hard. Combining it with error correction, which is specific for each user, makes the problem even more challenging. In this paper, we look at the optimization problem for multicast multi-access network configuration based on channel conditions of the users. The paper is a continuation of previous work [2][3][4], where we considered a solution for the network selection problem for heterogeneous mobile networking as a part of multicast group management.

The remainder of the paper is organized as follows. After presenting an overview of related work in Section II, we give a short introduction to forward error correction in Section III. We discuss a representative scenario in Section IV and present the problem formulation in Section V. The proposed heuristic algorithm is given in Section VI, before discussing future work and concluding in Section VII and Section VIII, respectively.

II. RELATED WORK

The research field concerning selection of a network in heterogeneous wireless networks from a perspective of multicast multipath delivery is not well explored. We found that previous work in the area of mobile multicast focuses on subjects like optimal multicast tree construction in multihop ad hoc networks [5][6][7][8].

Jang et al. [9] present a mechanism for efficient network resource usage in a mobile multicast scenario. This mechanism is developed for heterogeneous networks and implements network selection based on network and terminal characteristics and Quality of Service (QoS). However, in the proposed mechanism, the network selection is performed purely based on the terminal's preferences; the network perspective is not considered; and the solution does not optimize the utilization of network resources.

Hou et al. [10] propose a cooperative multicast scheduling scheme for multimedia services in IEEE 802.16 based wireless metropolitan area networks (WMAN). The scheduling is considered for one base station that further re-sends the data to multiple subscriber stations. These are grouped into different multicast groups and the users are assigned to the groups. The authors consider two approaches to select multicast groups for services: the random selection and the channel state aware selection. The process is controlled by the base station and limited to one network technology. Network heterogeneity is not considered.

The Multicast Mobility (multimob) working group [11] focuses its activity on supporting multicast in a mobile environment. The main goals of the group are to work out mechanisms for supporting multicast source mobility and mechanisms that optimize multicast traffic during a handover. The group also documents the configuration of IGMPv3/MLDv2 in mobile

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environments. In this sense, they extend the IGMPv3/MLDv2 protocols for implementation in the mobile domain and improve *Proxy Mobile IPv6* to handle multicast efficiently. However, they do not consider any modifications across different access networks.

In our analysis, we recognize that the presented previous work has not addressed several important aspects related to selection of multiple serving networks for mobile multicast groups. These considerations motivate us to look at the problem of building multicast groups that are capable of exploiting multiple simultaneous connections in heterogeneous mobile networks.

III. FORWARD ERROR CORRECTION

Forward Error Correction (FEC) [12] is a coding technique that is widely adopted for recovery of corrupted data. On the Internet, it is often used for data communication from senders to receivers through an unreliable or lossy medium and is widely discussed as a component for designing a reliable media streaming system for wireless networks [13][14]. Block codes are a family of FEC often used in telecommunications that encode data in blocks. The most commonly used among block codes is the Reed-Solomon coding [15]. Applying block coding, the sender encodes redundant packets and sends both the original and redundant packets to the receiver. The receiver can reconstruct the original packets upon receiving a fraction of the total packets. The coding takes k original packets and produces n-k redundant packets, resulting in a total of n packets. If k or more packets arrive at the receiver, the receiver is able to reconstruct all the original packets. It implies that the transmission needs larger n numbers for communications channels with higher loss packet rate. In this paper, we use Reed-Solomon codes as an illustrative example for our analysis. Though the choice of error correction methods is an important issue, we do not address this problem in our study.

IV. SCENARIO

To illustrate the yet unsolved challenges for optimal network selection in multicast networks, we consider a multimedia streaming scenario for a group of mobile users that concurrently receive the same content from the Internet. We assume that a backbone proxy server (BPS) is placed at the network edge. The BPS is a member of a content distribution network (CDN).

The BPS streams content that either is hosted on a streaming server, or re-sends the streaming content as a part of an application layer multicast. The users of this network are located in an area with a substantial overlap in coverage of several mobile networks, and are connected to different networks. The base stations of the system have multicast capabilities, implementing, for example, Multimedia Broadcast Multicast Service [16].

In our scenario, we assume that the mobile terminals are capable of connecting to several access networks and getting content from these networks simultaneously. Hence, users that get the same content can exploit the same wireless

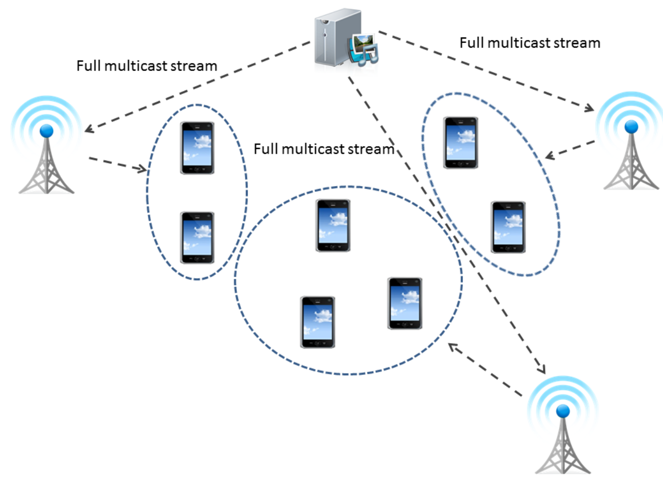

Figure 1. Multicast streaming scenario for a group of mobile clients receiving the same content.

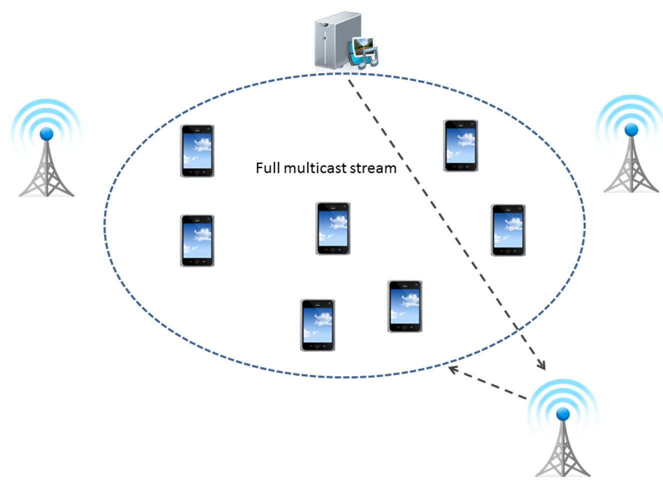

Figure 2. Multicast streaming case for mobile clients switched to one mobile network.

links because the content can be broadcast to them. Such configuration is beneficial as it saves network resources. However, these users may have different channel conditions, and it is important to consider these conditions while forming multicast groups. As the users experience different packet loss, the corresponding number of redundant packets required for successful decoding of the content varies for each user. The BPS can use this information to determine how users can be regrouped in multicast groups and how the multicast content can be split among the serving networks. For a multicast group, the number of redundant packets should be sufficient to provide equally good quality for all users of this group. Obviously, the number of redundant packets for each multicast group is calculated based on the user who experience the worst channel conditions. In the paper, we consider three typical cases of such regrouping.

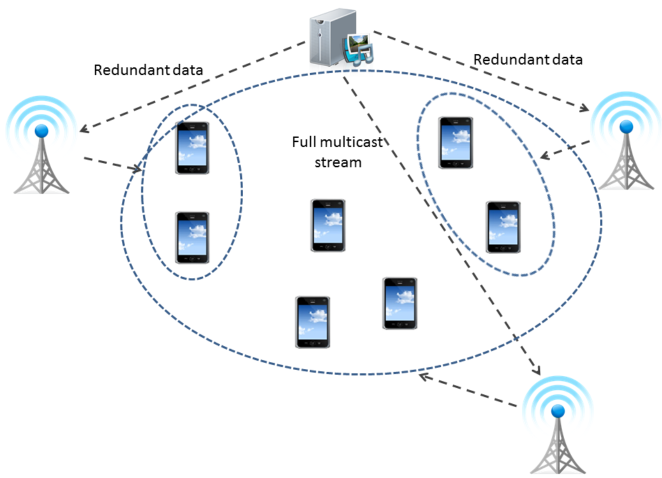

Figure 3. Multicast streaming scenario for a group of mobile clients.

A. Case 1

In this case, the users are allocated to the mobile networks with the best channel conditions. This configuration is depicted in Figure 1. This case requires the minimum number of redundant packets encoded for each group, however the original packets are sent multiple times through the network.

B. Case 2

All users can be grouped under one mobile network and only one multicast stream is formed, as depicted in Figure 2. In this case, the original packets are sent only to one network, but the number of redundant packet is higher, and the serving network needs to allocate more resources while the other networks are underprovided.

C. Case 3

This case is depicted in Figure 3. The users exploit multiple connections. The stream is split into original and redundant packets. The users are divided into groups similar to Case 1. Original packets are sent to one network along with redundant packets for the users from this network. Additional redundant packets for the rest of the system are sent to corresponding networks. In this case, the original packets are send to one network and, at the same time, the load is, to some extent, spread among all networks.

V. Problem Formulation

In this section, the scenario discussed in Section IV is formalized.

We consider a set of networks $N = 1, 2, \ldots, n$ and a set of mobile nodes $M = 1, 2, \ldots, m$ receiving the same content from the Internet. The content is sent at bitrate r. For each node m_j and network n_i, the following is defined: available bandwidths of networks are denoted by b_i; packet loss that node m_j experiences in network n_i is denoted by $l_{i,j}$. We define a decision variable $x_{i,j}$ as follows:

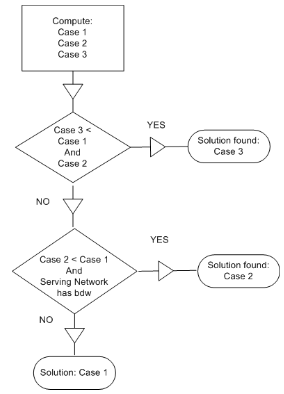

Figure 4. Heuristic Algorithm for Multicast Configuration.

$$x(i,j) = \begin{cases} 1, \text{if } m_j \text{ gets a portion of streaming content in } n_i \\ 0, \text{if not} \end{cases} \tag{1}$$

For each mobile network n_i, we define a function γ as follows:

$$\gamma(i) = \begin{cases} 1, \text{if at least one } m_j \text{ gets a portion of content in } n_i \\ 0, \text{if not} \end{cases} \tag{2}$$

We define a function θ as a relation between the packet loss and the number of packets needed for successful decoding.

We define a variable y_i as a number of packets per time unit sent to network n_i. To find the best possible multicast configuration in terms of minimization of consumed bandwidth, we minimize the following objective function:

$$\min \sum_{n_i \in N} \gamma(i) \cdot y_i \tag{3}$$

The objective function is subject to the set of constraints given below.

For each mobile node m_j, we need to guarantee that it can completely receive the requested content.

$$\forall\{j\} : \sum_i y_i \cdot x_i \cdot \theta(l_{i,j}) \geq r \tag{4}$$

For each network, the availability of its bandwidth is checked.

$$\forall\{i\} : y_i \leq b_i \tag{5}$$

This optimization problem is NP-hard and cannot be solved by common optimization solvers. We, therefore, need to consider a heuristic approach to problem solving.

VI. Algorithm

To work around the NP-hardness of the above formulation, we propose a simple heuristic algorithm for forming multicast groups. In Section IV, we considered three different cases.

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Though, Case 3 may look as an optimal one, it can be not optimal for some distributions of packet loss among users. Therefore, applying Case 1 or Case 2 may improve total bandwidth usage and we need to evaluate these cases as well. The operation of the algorithm is depicted in Figure 4.

VII. Discussion

The implementation of the algorithm in real systems requires that all knowledge of network resources and channel state information of users is available to the BPS or some other central unit that decides upon how the data transmission shall be constructed. This implies that a significant number of messages needs to be exchanged inside the system, which comes at the cost of increased delays, need for network resources, and computation resources on mobile devices. Also, once the information arrives at the BPS it can already be outdated because conditions in mobile networks can change quickly. To overcome this problem, we need an algorithm that is designed to handle the aforementioned information uncertainty. The problem discussed in Section V will be reformulated. It requires that the packet loss in Section V is replaced with corresponding probability values. A choice of an effective FEC scheme should also be addressed as a part of the implementation.

VIII. Conclusion

The paper outlines the problem of selecting the optimal network for multicast groups of mobile clients in multi-access scenario based on mobile clients' channel state information. We proposed a simple heuristic approach that provides the assignment for a given network topology and network conditions. Implementing the multipath solution for the multicast scenario in a multi-access network is challenging because the formulation of this solution is NP-hard. The proposed multipath multicast approach has certain limitations and needs further investigation.

References

[1] Cisco, "Cisco visual networking index: Global mobile data traffic forecast update, 2014-2019," 2015.

[2] S. Boudko, W. Leister, and S. Gjessing, "Multicast group management for users of heterogeneous wireless networks," in *CONTENT 2012: The Fourth International Conference on Creative Content Technologies*. International Academy, Research and Industry Association (IARIA), 2012, pp. 24–27.

[3] ——, "Optimal network selection for mobile multicast groups," in *ICSNC 2012 The Seventh International Conference on Systems and Networks Communications*. International Academy, Research and Industry Association (IARIA), 2012, pp. 224–227.

[4] S. Boudko and W. Leister, "Network selection for multicast groups in heterogeneous wireless environments," in *MoMM '13: Proc. 11th Int'l Conf. on Advances in Mobile Computing and Multimedia*. ACM, 2013, pp. 167–176.

[5] M. Gerla, C.-C. Chiang, and L. Zhang, "Tree multicast strategies in mobile, multishop wireless networks," *Mob. Netw. Appl.*, vol. 4, no. 3, pp. 193–207, Oct. 1999.

[6] C.-C. Chiang, M. Gerla, and L. Zhang, "Forwarding group multicast protocol (FGMP) for multihop, mobile wireless networks," *Cluster Computing*, vol. 1, no. 2, pp. 187–196, Apr. 1998.

[7] J. G. Jetcheva, "Adaptive demand-driven multicast routing in multi-hop wireless ad hoc networks," Ph.D. dissertation, Carnegie Mellon University, Pittsburgh, PA, USA, 2004.

[8] J. Yuan, Z. Li, W. Yu, and B. Li, "A cross-layer optimization framework for multihop multicast in wireless mesh networks," *IEEE J. Sel. Areas Commun.*, vol. 24, no. 11, pp. 2092 –2103, Nov. 2006.

[9] I.-S. Jang, W.-T. Kim, J.-M. Park, and Y.-J. Park, "Mobile multicast mechanism based mih for efficient network resource usage in heterogeneous networks," in *Proc. of the 12th Int'l Conf. on Advanced Communication Technology*, ser. ICACT'10, 2010, pp. 850–854.

[10] F. Hou, L. Cai, P.-H. Ho, X. Shen, and J. Zhang, "A cooperative multicast scheduling scheme for multimedia services in IEEE 802.16 networks," *Wireless Communications, IEEE Transactions on*, vol. 8, no. 3, pp. 1508–1519, 2009.

[11] Multicast Mobility Working Group, "Charter for Working Group," 2010, [Online]. Available: http://datatracker.ietf.org/wg/multimob/charter/, accessed July 30, 2013.

[12] G. C. Clark and J. B. Cain, *Error-Correction Coding for Digital Communications*. Perseus Publishing, 1981.

[13] S. Alamouti, "A simple transmit diversity technique for wireless communications," *Selected Areas in Communications, IEEE Journal on*, vol. 16, no. 8, pp. 1451–1458, Oct 1998.

[14] A. Nafaa, T. Taleb, and L. Murphy, "Forward error correction strategies for media streaming over wireless networks," *Communications Magazine, IEEE*, vol. 46, no. 1, pp. 72–79, January 2008.

[15] I. S. Reed and G. Solomon, "Polynomial Codes Over Certain Finite Fields," *Journal of the Society for Industrial and Applied Mathematics*, vol. 8, no. 2, pp. 300–304, 1960.

[16] G. Xylomenos, V. Vogkas, and G. Thanos, "The multimedia broadcast/multicast service," *Wireless Communications and Mobile Computing*, vol. 8, no. 2, pp. 255–265, 2008.