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ADAPTIVE VIDEO MULTICAST STREAMING OVER MULTIRATE WIRELESS LANs

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Abstract. Video multicast services over wireless network has become widespread nowadays. Multicasting over wired networks approach can not be directly transfer and assumed to wireless network. In this paper the overview of such problems of wireless multicast is considered. The main factors for wired multicast for video streaming are discussed. An analysis and an overview of existing mechanism for multicast video streaming are given.

Keywords: multicast, video streaming, wireless network.

Introduction

The video streaming has become one of the popular application driving wireless LAN nowadays. But multicast protocols over wireless network have some challenges. Noise, multipath, interference, and mobility of hosts cause rapid changes of channel condition in wireless environment [11].

The most growing network technologies in wireless communication is IEEE 802.11 wireless LANs (WLANs). But there are two main problems, which are faced effective deployment of multicast services over WLANs. Firstly, in the IEEE 802.11 standards it is determined, that multicasting is a simple broadcasting mechanism, where the Acknowledgement (ACK) frames are not used. Such nonavailability of feedback mechanism of course makes a very strong affect on the reliability of the service, which will be provided to the user. The second problem is that according to the IEEE 802.11a/b standard all frames with multicast and broadcast Receiver Address (RA) should be transmitted at one of the rates included in the basic rate set. But in the standard it is not defined how the best rate can be chosen. Also it is not specified how the rate can be adopted according to the spectrum of the possible current wireless channel conditions during the time [11].

In the second section the small summation of the technologies in video streaming is presented. The focus of the paper is the multicast technology. The first goal of this paper is to consider existing problems in wireless video streaming and find out what makes it difficult to extend the actual wired approach. The second aim is to make overview of existing mechanisms for multicast video streaming and to make an analysis of pros and cons of them.

1. Video Streaming and Variants of Implementing of Technology

In all streaming media is multimedia that will be transferred from provider and is constantly received by and displayed by an end-user [15]. The common form of streamed media can by presented by the Internet television. The video streaming has become especially popular since 2000s. The main reasons for that are increasing of network bandwidth and increased access to the Internet for average user. This method of processing of delivering media now is also a competitive approach, such as downloading.

There are some protocols which support streaming media. One of them is User Datagram Protocol (UDP) where the streaming data is sent as series of small packets. This protocol hasn't got guarantee of the delivery, so it is make it difficult to detect loss or corruption and recover data. Also, if it happens that the data is lost, the stream can be dropped out.

Also there are reliable protocols which guarantee correct delivery of each bit in the media stream, such as Transmission Control Protocol (TCP). However, if there is a large amount of errors by connection or by confirmation of received information, then the transmitted information can became irrelevant. It can also cause significant delays in the transmission of information on the time spent on sending corrupted data. About such delays, which can be significant critical for the real-time multimedia communication, it will be mentioned in third subsection in the next section.

Unicast protocols send from a server to each node an individual copy of the media stream. These not-scalable protocols also can be burdened for network equipment.

Multicast Protocols, as were said above, are developed to decrease the load on servers if there is a large number of customers getting a streaming multimedia.

2. Multicast

Firstly, it should be mentioned what is multicast commonly means. Multicast is a type of group communication where there is a one sender who transfer the information to a group of destination nodes simultaneously [12]. Multicast in computer networking can be implemented at the Internet layer with the method of IP multicast which sends IP datagrams to a set of interested receivers in a single transmission [13].

Some applications, such as distance learning, sending email, radio, video on demand, video conferencing, support multicast. In unicast network an individual connection with each received node is set even when there is consumption of one resource on the common route. In multicast communication a source node sends only one copy of the data for the common route to recipients who has a subscription. The advantages of this approach are that, if it has added new users in subscription, then there is no need to increase bandwidth for a common route to consumers. Accordingly, the load on the intermediate equipment will be reduced [5].

2.1. Characteristics of Wired and Wireless Multicast

Wired multicast, where there is a fixed number of users, can be extended also to a wireless environment where there are changing numbers of mobile users. But direct transfer of this approach to the wireless multicast can cause some difficulties (see Table 1). For example, the bandwidth, which is available in the two directions of any given wireless link, can be unequal. Furthermore, they can be unidirectional. That can influence transferred information which is sent between two mobile nodes, and it can lead to some problems. Inefficient multicast tree/mesh, loss of packets, incorrect routing, even the discarding of multicast packets — all can take place and effect certain consequences [10].

2.2. Requirements on Wireless Multicast Video Streaming

The world of wireless multicast application is very broad, so requirements, which wireless multicast serves must fulfill, are very different. In the paper of Varchney six application categories are given: interactive games, mobile and locational advertising, mobile distance education, proactive service management, product recommendation systems, management, product location and search [10]. Also, the six groups of multicast requirements are present which are characterised for these types of application. From this table it is possible to extract requirements which suit not just mobile nodes, but also common applications and to the focus of this paper — video streaming.

So, for video streaming high bandwidth and very low delay are very important, such as a few hundred ms. Secondly, service interruptions due to intermittent connectivity or brief disconnectivity significantly affects the users' overall experience. Thirdly, reliability and QoS requirements are very significant. But requirements, such as security and privacy, are not critical for multicast video streaming.

2.3. Real-Time Multimedia Communication and It's Requirements

Real-Time multimedia communication is a special sort of multicast streaming [8]. Real-time voice and video data must be synchronous and ideally must be processed without delay. Of course, in reality it is not possible to process without delay, but the most important challenge for real-time communication is to minimize this delay.

The voice and video data streams can be considered as a sequence of samples which have finite size. Also samples must be generated, transmitted and received at fixed time intervals which must not be gone over this time limit. So, there are four types of such time constraints: *sampling*, *packetization*, *network transmission* and *presentation* delay. The delay between the generation samples of the stream object is called sampling delay. The packetization delay is the time interval which is required to generate a sample and transfer it to the network. The time, that

Table 1. Qualitative comparison of wired and wireless multicast [10]

Issue	**Current "wired" multicast**	**Wireless and mobile multicast**	**Possible ways to support wireless and mobile multicast**
Type of links	Symmetrical and fixed characteristics Broadcast links in LANs	Possibly asymmetrical and/or unidirectional links of varying performance and point-to-point links in cellular and PCS	Design of new protocols to handle route asymmetry and unidirectional links without reverse-path information (possible history and prediction-based schemes)
Bandwidth	Plentiful	Limited and variable amount	Protocols to adapt membership management and routing updates to the amount of bandwidth available and user mobility
Topology	Fixed	Fixed in infrastructure-based, dynamic in ad hoc networks	Protocols for both fixed and changing topology by "sensing" topological changes
Loss of packets	Infrequent ($<$ 1%)	Frequent and variable (1%-30% based on links)	Error control with possible retransmission from neighboring user(s)
Membership changes	Only when a user leaves or joins a group	Also when a user moves to another location	Protocols with reduced overhead for managing membership
Routing	Fixed routing structure throughout the multicast session	Routing structure subject to change due to user mobility	Protocols that could dynamically adapt the routing to current structure and available resources
Security Issues	Less complex due to fixed users and wired links	More complex due to wireless links and possible use of broadcasting	Encryption and security techniques in routing and membership management
Quality of service	Individual routes can use RSVP	Due to user mobility, RSVP may cause excessive overhead	Design of new protocols for "soft" QoS under varying link conditions and mobility
Reliability	Possible use of a transport-layer protocol (such as the Multicast File Transfer Protocol)	More complex due to wireless links and user mobility: possible unwanted interaction of protocols at transport and link layers	Design of new protocols that could allow one or more different retransmission schemes at one or more protocol layers

needs to transmit the sample over network, is called network transmission delay. Finally, presentation delay is the time which is requisite for buffering the sample before presenting it to the user. The last three delays also can be called by the common term — transmission delay.

In a local area network environment the most dominant delay is the packetization delay [8]. Also, the choice of the sample size plays important role in magnitude of this delay. That is why the size of one sample should be chosen so that the packetization delay would be acceptable.

As it was said above, the big problem by real-time communication is a maximum allowable streaming delay. And a significant different real-time communication from generic streaming is that a late packet is also not useful as a lost packet. This means that is no sense to use acknowledgement packets to detect lost packet by user. It happens because retransmitted packet often come out of timeout which is appropriate for real-time communication.

3. The Problems of Multicast Video Streaming in WLAN

As it was said in the third section, wired multicast for video streaming can be also extended to a wireless environment, but there are certain challenges which will be described in details further. The main reason of it is the transfer to wireless network adds some network performance characteristics. Variable data rates, packet loss, and multicast unreliability include in new consent and do not settle in the traditional approaches to guaranteed quality of service (QoS). So, in following sub-sections these characteristics are described [3].

3.1. Variable Data Rate

The first important difference between wired and wireless environment is the data rate of transmission in wireless network which changes over time. Also, the data rate in WLAN in opposite to wired network depends on the distance of the client from the access point (AP). For example, if a wired connection in the second type of network is operating at 100 Mb/s today, it will operate at 100 Mb/s also the next day. The one of consequences of such data rates is the throughput of individual video flows and the capacity of the overall network which changes with time [3].

The traditional QoS approach of bandwidth reservation and admission control do not suit such variable throughput and capacity. For example, the client can operate at 54 Mb/s, and the requested video stream rate is 10 Mb/s. The system recognizes that the necessary airtime for the new stream can be accommodated, and so accepts the stream. If after that the client goes away from the access point, the data rate of the client drops to 6 Mb/s. So the client data rate become smaller as by requested stream, and the video stream can not be supported anymore. Thus, sending video over a wireless network can be considered as sending video over the public Internet, due to widely varied user's experience and throughput over time.

3.2. Packet Loss

Another problem of wireless network in comparison to a wired is the relative unreliability of the underlying Layer 2 transport. So-called unreliability is that in WLAN environment much more packets are lost than wired.

The first reason of packet loss is collisions: two devices, which are connected with WLAN, attempt to transmit at the same time. There is a prevention measure, the "listen-before-talk" medium access method, against such collisions in a shared half-duplex medium which WLAN uses. But all of them can not be avoided. This situation can be escalated if non-wireless devices work in the same band as WLAN devices. Most of them do not communicate, following the "listen-before-talk" algorithm, and so collisions can be faced.

The second reason of packet loss is that wireless transmissions suffer from short-term signal loss or fades. Fades can appear due to some physical properties of objects, for example due to absorption from intervening objects in the environment or reflections of waves in the environment accidentally causing signal cancellation.

The third factor of packet loss is that in WLAN systems are trying different rates for the best transmission rate. So, by hunting of the best, some packets can be lost during the search process.

If all these reasons will be summarized (combination of collisions, fades, and data rate selection), an underlying packet error rate (PER) can give 5 percent. For the error compensation, in wireless network the retransmission mechanism can be used. Packets, which are not successfully received and acknowledged, can be resent. This mechanism often helps to reduce the final packet loss rate (PLR) to less than 0.1 percent. The other side of the coin is that these retransmissions cause jitter [1] and take network throughput, both of which can influence QoS. And even after work of retransmission mechanism, the final PLR can stay still much higher than is typically observed on wired connections.

3.3. Multicast Unreliability

For the wireless multicast traffic the underlying packet error rate plays an important role. In wireless network there is no according retransmission mechanism for multicast with multiple receivers. So the PLR for multicast traffic stays equal to the PER. As a result, the final packet loss rate for wireless multicast traffic can be about 5 percent. In worst case, it can be very big problem for video where loss of even a single packet can result in an error that spreads for many video frames. For this reason, it is quite normal situation for multicast video applications, which work on a wired network, to fail completely when they operate on a wireless network.

Variable data rate, packet loss, multicast unreliability — each of these factors can strongly influence a video, so the application must handle by itself how to manage this situation and decries the impact of these three factors.

4. Overview and Analysis of Existing Dynamic Rate Adaptation Mechanism for Multicast Video Streaming

In this section we present some new proposals to liquidate mentioned problems. All these proposals concern a popular method of Dynamic Rate Adaptation [1]. To understand the backgrounds and foundation of rate adaptation mechanisms designed for multicast transmission, we also demonstrate pioneer rate adaptation mechanisms in IEEE 802.11 for unicast transmission.

[1] Jitter is the deviation from true periodicity of a presumed periodic signal in electronics and telecommunications, often in relation to a reference clock source [14]

4.1. Rate adaptation mechanisms in IEEE 802.11

The first proposal and widely used rate adaptation protocol in commercial is a result of Kamerman and Monteban — Auto Rate Fallback (ARF) [6]. The main idea of ARF-protocol is when signal to noise ratio (SNR) decreases, then an access point tries to recover by decreasing the bandwidth. The process of increasing and decreasing of the rate by access point take place as follows. If the access point successfully receives a certain number of packets (10), then it switches to a higher rate. It decreases a rate if a failure occurs right after rate increase. That means that the access point switches to a lower rate if there is two consecutive failures of 10-sequence transmissions. This mechanism was implemented in a lot of numbers of commercial products, and the feedback of this approach is positive, but also has got a big minus. Because of the static-thresholds, it can not be adapted well to varying condition in wireless networks.

To take this drawback away, Lacage et al. have proposed dynamic-threshold method Adaptive ARF (AARF) [7]. The authors got threshold-based mechanism as in ARF as basis, but they do not use the fixed number of the threshold. The main idea of this mechanism is to calculate binary exponential threshold at runtime to make the mechanism better reflect the channel conditions. For the calculation of new higher rate, the last number of consecutive successful transmission must be multiplied by two. The advantage of this mechanism is that the period between successive failed attempts to use a higher rate is increased. Also it is made in fewer failures and retransmissions, so the overall throughput is improved. As shows practice, the AARF-mechanism is relatively efficient, but it cannot be used in multicast transmission. The reason of that is that in implementation of this protocol acknowledgement and retransmission which are disabled in multicast are used.

Holland et al. proposed another popular protocol — Receiver-Based Auto Rate (RBAR) [4]. The main aim of this approach is to optimize the performance in wireless networks using rate-adaptation mechanism at MAC layer. The authors use some kind of communication mechanism — Request/Clear To Send(RTS/CTS). This channel probing mechanism is enabled in order to get/send feedback from receiver. RTS frame is always sent out before any transmission by sender. This frame will be obtained by the receiver who computes the SNR of the frame. Then the receiver sends back the transmission rate which is got from a mapping table of SNRs and rates. And then this new transmission rate will be used by sender in the next transmissions in CTS. In this implementation the headers of the RTS and CTS have been modified for the purposes. The first disadvantage of this protocol is that the SNR which is used for calculation of new transmission rate, is a physical parameter that does not always correlate well with human perception. The second disadvantage of RBAR is unavailability for multicast transmissions, because RTS/CTS are unusable in those cases.

4.2. Rate adaptation in wireless multicast

Basalamah et al. developed Rate Adaptive Multicast protocol (RAM) which is based on similar idea of using RTS/CTS in RBAR for channel evaluation and selection of rate. The RTS frame is used by multicast receivers to estimate channel condition, and based of it, the receiver send back transmission rate for sender to use in CTS. If the multicast node do not receive the data frame correctly, this node must send a NACK (Not Acknowledge). Frame sequence field is added to RTS for enhancing the throughput and it is used by member of the multicasting to control which data frame is received: a new frame or retransmission of a previously successfully received frame. If a frame is marked as retransmission frame, then a member will not participate in the multicast transmission. Because of aforementioned technique, this field helps overall to reduce the number of retransmission. As a disadvantage can be mentioned that the protocol makes use of RTS/CTS, NACK and retransmission which are disable in multicast. Also, due to retransmission and additionally field in RTS, it is received many frames which are already exist.

To solve the problem of oversaturated feedback, the Leader-based Rate Adaptive Multicasting for Wireless LANs (LM-ARF) protocol was proposed by Choi et al [2]. This protocols, which is based on ARF, uses the same data rate adaptation mechanism, but also uses leader-based feedback. One of the receiving stations is chosen as leader, and it is responsible for sending ACKs on behalf of the stations which are participating in multicast communication. If the station, which is not marked as leader, cannot receive a multicast frame, it must send a negative acknowledgement (NAK) to request retransmission. The access point keeps fairness between unicast flows by uniform distribution of window size the same way as that of a unicast transmission. In this protocol a new frame type is added — CTS-to-Self frame which serves for guarantee of the channel access and announcement of the transmission of a multicast frame. This protocol has a lot of advantages such as fairness, reliability, effective and good performance, but there is also a disadvantage as in ARF — static-threshold approach and other drawbacks of ARF as well.

Villalón et al. proposed Auto Rate Selection for Multicast (ARSM) protocol which instead of using RTS/CTS uses multicast channel probe operation (MCPO) [11]. This operation must be processed before multicast traffic will be sent: access point must send out the multicast probe frame. The user, which have the lowest SNR, must reply to the access point by multicast response. After that, the access point select the multicast data rate which based on type of response: explicit, implicit, and no feedback. Also, in this protocol there is implemented mechanism to avoiding collision: multicast users select backoff timer according to their SNR value.

Another effective protocol was proposed by Park et al. : SNR-based Auto Rate for Multicast (SARM) [9]. Authors are taking into account user perception in this protocol, and the transmission rate will be adapted according to node's SNR which has the worst channel condition. SNR references are mapped in one table where the each element must be higher than 30 to represent good quality, for each transmission rate. The practice is showed that the wireless channel can be used more efficiently if multicast transmission rate will be changed based on SNR values. To solve the feedback problem, it is proposed to make a channel probing mechanism and after that send notification to the AP. To avoid collision during feedback transmission to the access point, as in ARSM, it uses a backoff timer based on the SNR.

For better representation, the protocols, which were considered above, are summarized in Table 2 below.

Table 2. Summary of Rate Adaptation Protocols

	Protocol	**Threshold**	**Feedback**
Unicast	ARF	static	ACK
	AARF	dynamic	ACK
	RBAR	static	RTS/CTS
Multicast	RAM	static	RTS/CTS, NACK
	ARSM	static	Channel probing
	LM-ARF	static	Leader-based
	SARM	static	Channel probing

Conclusion

In recent years, the interest to video application over wireless network rises up. As was mentioned in section two, multicasting is an relative effective technology of data transition to a group of users. The reason for that is that the data is transferred to a group of destination nodes simultaneously, i.e in a single transmission. However, the high packet loss ratio and bandwidth spectrum of wireless channels produce a problem for video multicast over wireless networks [1].

In this paper we give an overview of the mechanisms for multicast video streaming which solve these problems by a method of dynamic rate adaptation, and mechanisms for unicast which were used as foundation for the next researches in multicast direction.

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АДАПТИВНАЯ ГРУППОВАЯ ПЕРЕДАЧА ВИДЕО ЧЕРЕЗ БЕСПРОВОДНЫЕ ЛОКАЛЬНЫЕ СЕТИ С РАЗНОЙ СКОРОСТЬЮ ПЕРЕДАЧИ

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Аннотация. Службы групповой рассылки видео через беспроводные сети сейчас широко распространены. Подходы, используемые для групповой передачи данных в проводных сетях, не могут быть напрямую перенесены в беспроводные среды. В данной работе рассматриваются проблемы групповой рассылки в сетях беспроводного доступа, основные механизмы проводной групповой передачи видео потоков, даётся обзор и анализ существующих механизмов групповой передачи видео потоков.

Ключевые слова: групповые рассылки (multicast), видео потоки, беспроводные сети.