Towards the Optimization of Video P2P Streaming over Wireless Mesh Networks

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Abstract. P2P overlay networks are large-scale distributed systems. They are used mainly for data sharing and content distribution and can be more efficient than the traditional client-server data models. On the other hand, emerging Mesh networks are effective solutions for ubiquitous broadband access. High throughput, cost effectiveness, and ease of deployment are key features of these networks. The deployment of P2P systems over mesh networks is the main topic of this paper. Both systems need to form multiple shortest path trees in order to transfer data and the joint optimization of these systems, using a cross layer approach, promises good gains in terms of data throughput and fairness. In this paper, we describe the current solutions on Video P2P Streaming and we discuss some research opportunities to be addressed on our work.

Keywords: P2P, Video, Streaming, WMN.

1 Introduction

In the past years, we have assisted to a change of the Internet paradigm. The global network is evolving from a homogeneous network topology to a emergence of heterogeneous and mobile topology. In addition, WLANs are changing the way people access Internet, supporting the network concept of always connected, anytime, anywhere.

From all the new kinds of computer networks, Peer-to-peer (P2P) is playing a decisive role on today's Internet. The traffic produced by this type of overlay network is now dominant in the total Internet traffic [1].The emergence of P2P networks can be seen as a response to the inefficiency of the traditional server-client model, incapable of meeting the demands of a global network that grows at an increasing pace, where clients can have processing power similar to those of servers. These overlay networks build up in a dynamic, distributed way, with capacity of auto-configuration, among other features. The serverless approach allowed the introduction of new applications and services, with file sharing being the most prominent. Other services, however, are now emerging and subject of more research such as video broadcast over P2P networks.

Network protocols are commonly divided into several independent communication layers, which interact through interfaces. The most successful network stack is TCP/IP that comprises physical, medium access, network, and application layers. This model was designed based on the wired networks of the original Internet whose physical topology is static. Wireless Networks have characteristics such as high latency, lossy links, and constant-changing capacity; applying the old TCP/IP model to them can lead to suboptimal use of the network resources due to the lack of cooperation between the lower layers (Physical, MAC, and Network). On the other hand, overlay applications such as P2P do not usually consider the conditions of the lower layers such as their current routing tables. This has a special importance in Ad-Hoc networks and mesh networks since the constant changing topology impacts the system performance.

This paper is structured as follows: section 2 presents our motivation and the research scenario, defining research questions to be addressed. Section 3 gives an insight on the technical background. Section 4 shows the current trends on the video P2P streaming area and Section 5 presents the research challenges to be addressed on our work. At last, in section 6 we draw our conclusions.

2 Motivation

Video-over-IP traffic is rising in recent years as the number of Internet users interested in this type of media is increasing. The year of 2008 saw an increase of video streams delivered through professional content sites in 43.4% to 33.5 billion [2] online video views without considering user-generated videos. In middle 2006, Youtube [3] hosted around 45 terabytes of information, having more than 1.7 billion views [4].

The client-server service model is the typical solution for streaming over the Internet. The client establishes a connection to a video server and asks the transmission of a given video content, which is then streamed by the server if the request was successful. One of the most challenging concerns of video streaming server solutions is scalability. To provide a good quality stream, high bandwidths are required. Video source servers should have bandwidth provision that grows with the number of clients. These provisions can have significant costs for deploying server based video stream solutions.

P2P networks break the traditional server-client model to build a distributed system. Since all nodes act as both client and server, they not only download data but also upload to other nodes on the network. This topology enables a more efficient use of the upload bandwidth of the users, reducing in this way the overall bandwidth load of the network. P2P file-sharing applications such as Napster [5] or more recently, Bittorrent [6] Limewire [7], and eMule [8] allow a fast diffusion of data files on the Internet. More recently, P2P applications have emerged to provide video streaming services, both live video or on-demand. Some of the current deployed applications are PPLive [9], PPstream [10], Sopcast, [11], and TVUplayer [12].

Since P2P is an overlay network, it relies on a physical topology. In general, P2P applications do not take into account the physical topology when they choose the neighbors. This can lead to suboptimal routing schemes at the network layer, with lower throughput and higher delays. Figure 1 shows a possible map between the overlay links and the physical networks links. A single overlay hop can translate into multiple physical hops, which leads to higher waste of bandwidth.

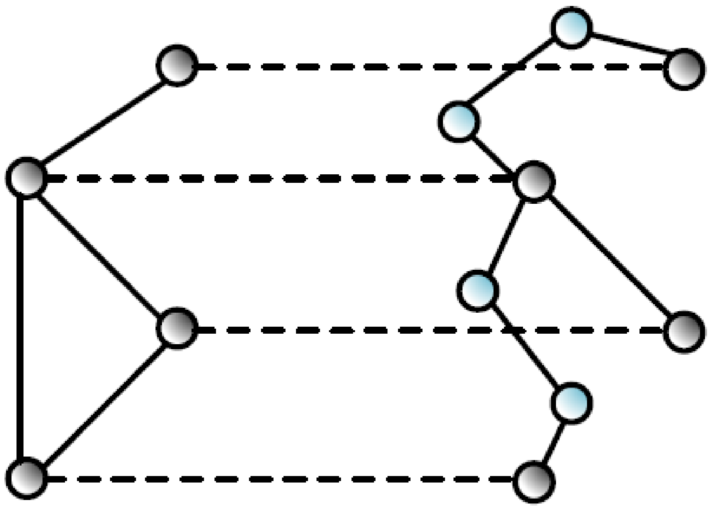

Fig. 1. Logical and physical connections mapping on a P2P system.

In the typical case of the global Internet, is difficult to change the physical topology and better match P2P requirements due the static link connections between the nodes. However, in scenarios where wireless and mobile nodes form mesh networks, the same limitations do not apply, especially if the usage of the P2P resources is confined to the mesh network.

Wireless Mesh Networks, such as 802.11s [13], have a set if features that makes them potentially capable of improving the performance of P2P applications: mesh networks are scalable; the neighbor links can be easily changed on demand; its ad-hoc characteristic enables an intrinsic P2P behavior, which can benefit P2P services, particularly the low-delay required services like video streaming. The ability to change both topologies enables that the overlay and physical layers to be mapped in a more effective way to provide better performance.

Real life scenarios employing P2P video broadcast could benefit from a better exploration of mesh networks capabilities. One of such scenarios is the public transportations as depicted by Figure 2. In this scenario buses would act as mesh nodes, with capacity to connect with other buses or bus stops, establishing a decentralized network.

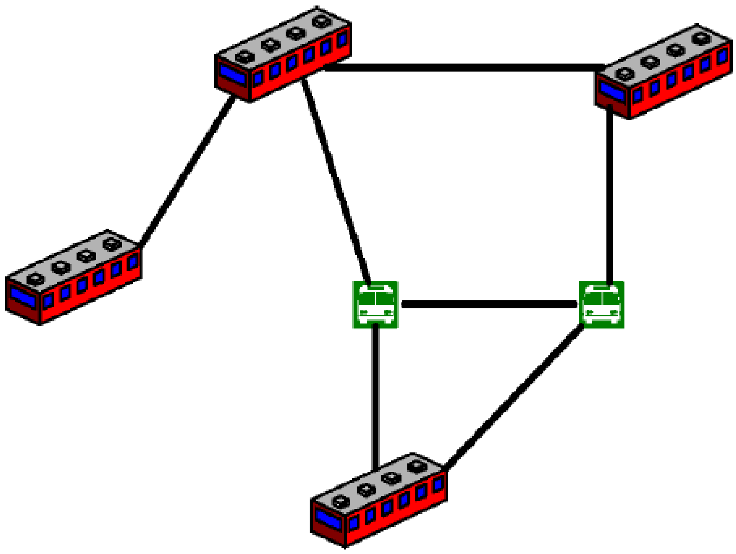

Fig. 2. Possible scenario for WMN implementation based on a public transportation system.

3 Technical Background

In this section, we present a brief technical background on P2P and Wireless Mesh Networks.

3.1 Peer-to-Peer Networks

Peer-to-peer networks are essentially an overlay topology based on a distributed system paradigm, where the end nodes, peers, are not usually constrain to a central organization [14]. Each participating node can operate both as a client and as a server and define direct links to neighbors at the logical application level. This kind of organization promotes equality among the nodes, allowing them to build a robust self-organized overlay network upon the original IP network.

P2P overlay networks can provide a vast list of features such as fault tolerant network architecture; resource sharing; distributed and redundant storage; searching mechanisms without relying on centralized entities; anonymity; high scalability.

In addition, P2P allows the deployment of services present on centralized architectures as hierarchical naming, trust, authentication, and search capabilities. Each peer contributes its capabilities to improve and scale the overlay network as storage space, computational power, and bandwidth. The distributed characteristic of P2P is highly valuable for various scenarios such is file sharing, multimedia distribution, and real time data that can exploit the P2P features to overcome the issues commonly attached to central management systems.

3.2 Video P2P Streaming

P2P Video broadcast is a specific type of P2P applications focused on redistributing video streams over the network. P2P video distribution systems can be classified as tree-based and mesh-based.

In tree-based systems, the overlay structure is typically well defined. Each child peer receives data through their parent peer.

However, this kind of layout is very vulnerable to peers departure. When a peer leaves the system, it will stop the streaming of video to its children peers, having the latter to cope with the loss by finding another parent. Commonly, tree-based systems follow a single-tree model or a multi-tree model.

In single-tree systems, users form a tree, at the overlay level, that has its root on the streaming server. Each participating peer, joins the network at a certain level, receives the video streams from its parent, and is responsible of forwarding the stream to its children. The joining process should be able to balance the tree as much as possible to minimize the delays of the peers at the bottom level. Tree maintenance is also important due its fragility to node departures, which disrupts the stream for children node. To minimize the impact of a leaving node, some mechanisms can be employed like the using of timeouts to detect a departure. This can be managed by a central entity or in a distributed system.

In multi-tree systems, the server divides the original stream into multiple sub-streams, creating this way multiple sub-trees, one for each sub-stream. When a node joins the networks, it tries to connect to all sub-trees needed to retrieve the video. In addition, a peer can be at different levels on each of the sub-trees.

On the other hand, swarm-based systems, try to avoid the former hierarchical architecture, in order to avoid the single-point of failure characteristic of the tree-based systems. Mesh-based systems can maintain multiple parent connections at same time and can change the topology dynamically. Peers can connect randomly to neighbors and can be a parent or a child of a given neighbor on different instances. Several applications follow this model such as [15] [16]. A recent study [17] showed that mesh systems have better performance than tree systems, concerning bandwidth usage, resilience and self-healing.

3.3 Mesh Networks

Wireless Mesh Networks (WMN) is an emerging wireless technology vowed to change the paradigm of network topologies. Internet Service Providers as well as end-user are showing an increasing interest on this technology because of its broad list of features, namely its robustness and reliability at a low cost deployment.

WMN are dynamically self-organized and self-configurable, where the nodes are capable to establish an ad-hoc topology and maintain the mesh connectivity. This model allows easier network maintenance, reliable service coverage, and sustainable scalability. WMN also employs advanced radio technologies, like multiple radio interfaces and smart antennas, increasing the network capacity.

Some features of WMN are as follows: **increased reliability** - the possibility of having redundant paths eliminates the single point failures and reduces bottleneck links; **low installment costs** - using the traditional infrastructure topology to deploy wireless networks on metro scale scenarios, would require a large number of higher cost access points while using less expensive WMN enabled nodes would reduce the total cost of the network whilst maintaining a high level of connectivity for all nodes; **large coverage area** - with the multi-hop capability of mesh networks, the covered area can be significantly increased; **automatic network connectivity** - WMN enabled nodes are capable of finding and establishing connections to its neighbor, providing network connectivity.

WMN usually comprehends two types of nodes: mesh routers and mesh clients. Besides the common routing capability for gateway functions, mesh routers contain additional functions to support specific mesh networking requirements. Multi-hop communications not only allow larger coverage areas but also the same coverage area of a regular wireless network to be achieved by a mesh router with much less transmission power. The flexibility of WMN can be improved by using mesh routers with multiple interfaces, even for different technologies. Mesh routers are supposed to have low mobility in order to provide a solid network backbone for the mesh clients.

Mesh clients, which also have some routing functionalities, can have a simpler hardware platforms when comparing to mesh routers. Moreover, mesh routers have the capability of integrating the mesh network within various other networks, bestowing WMN of diversity facilities, which makes this technology more than a simple ad-hoc network.

4 Related Work

In this section, we focus on current work done related to P2P and WMNs as well as propose some research directions in this area.

The need to improve P2P networks performance taking into account not only the logical but also the physical topology of the network is a subject already addressed by the community. We can divide the work on this area in two branches: generic P2P and video streaming specific P2P with each one sub-divided in solutions for WMN or for general networks. [18] [19] [20] [21] are works on generic P2P that can provide an insight on how the application network layers can interact, based on cross-layer design, in order to optimize the performance of P2P using cross-layer mechanisms. Moreover, [20] [21] provide information in how to exploit the characteristics of WMN to achieve better performances.

On the other hand, in Video P2P Streaming [22] [23] [24] [25] provide useful information on the special characteristics of Video P2P Streaming, in both WMN and non-WMN scenarios.

5 Research Challenges

In order to improve the overall network performance on P2P video streaming our research work should take into account:

- The characteristics of P2P applications for real-time video streaming over WMN;
- The characteristics of Mesh networks;
- Novel MAC layer approaches used to improve mesh networks performance;
- Node mobility and network mobility.

Analyzing the current solutions, we can find room to introduce improvements to video P2P streaming on WMN. Consider figure 3 that depicts an overlay network based on a swarm Video P2P solutions deployed over a WMN:

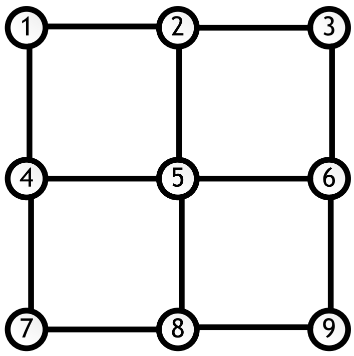

Fig. 3. Mesh network.

Assuming that more than one node will be watching the same stream, is expected that these nodes will need the same video chunks. If node 6 requests a given chuck to the overlay network and node 1 accepts the request, the latter will send the chuck to node 6 after finding a route using a given routing protocol. In the case of the route be 1-4-5-6 and node 4 also needs the same chuck, even if it did not requested the chunk yet, a cross-layer approach could be used to allow the network layer inform the application that a potential needed chunk is being forwarded by the node. This would avoid node 4 to request the same chuck later. We could also extend the previous approach, considering that every node would be monitoring every transmission at link layer and inform the upper layers when a potential needed packet is captured. This approach can have some drawbacks such as higher energy consumption.

Other approach could be clustering the network in order to avoid request flooding on the WMN, where the nodes nearer to the source would have the most recent chunks. This could be particularly interesting on mobility scenarios like in cases when a node is moving away from the source to an area where it could be used as a new source since it has newer chunks.

Based on the presented research challenges, our work has the potential to produce the following original contributions:

- A new routing protocol that meets the objective of improving the performance of the network based on the application and link layers changing characteristics.
- Enhanced P2P video streaming applications over Wireless Mesh Networks.
- Improved P2P mobility in scenarios where peers and mesh nodes move.

6 Conclusion and Future Work

In this paper, we presented the emerging Video P2P streaming solutions over WMN and the motivation of our research work. After showing some technical background, we indicated the current related work and the research challenges on this area.

Our approach will focus on real-time video streaming and should evaluate solutions based on tree or swarm model, support location awareness, minimize duplicated content and improve mobility for an uninterrupted service.

This research should lead to the creation and validation of new routing mechanisms that allows optimizing the available resources and ultimately improving the overall system performance. To meet the aforementioned objective, the problem shall be addressed in three phases: requirements evaluation through an extensive literature review; simulation using suitable software in order to test and validate the preliminary solutions; implementation of a valid solution in a real system in order to assess and confirm the results obtained through the simulations.

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