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CONTRIBUTIONS TO THE ENHANCEMENT OF MULTICAST ROUTING

by

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1 INTRODUCTION

As the Internet grows, new communication needs arise like real-time video and audio. In this case traffic should be sent as efficiently as possible, the solution being the use of multicast. Before multicast two communication paradigms were available, *unicast* and *broadcast*, both of which inadequate. The first one is *unicast* with one source and one destination. In order to send to multiple destinations, different communication paths are requested between the source and each of the destinations. Therefore, a copy of each audio and video stream needs to be sent separately to each receiver. As the number of destinations increases so does the load on the source and on the network. The second choice is b*roadcast*. It saves a lot of bandwidth compared to unicast, but is still insufficient because we probably need to send data to only some of the computers, not all, and also broadcast packets are traditionally not forwarded by routers. Thus, broadcast is good for applications and protocols that don't need to cross LAN limits.

2 ORIGINAL CONTRIBUTIONS IN THIS THESIS

This section presents the contributions to the enhancement of multicast routing contained in the thesis and their conclusions. All the results were published in journals and at international conferences in the field of networking.

1. **Classification of unicast and multicast routing protocols for interior and exterior routing.** The theoretical part is accompanied by practical experiments regarding distance vector routing protocols (RIPv1, RIPv2, RIPng) and link state routing protocols (OSPFv2, OSPFv3). The purpose was the development of a testing infrastructure for multicast routing protocols (DVMRP and PIM). The solution is based on open source implementations in Linux/FreeBSD that, further on, permitted the implementation of the contributions proposed in the thesis.

   References: [Blaga 04a, Blaga 04b, Blaga 04c, Blaga 04d, Blaga 04e]

2. **Study and classification of alternative group communication technologies like: CastGate, XCast, XCast+, ESM and HyperCast.** CastGate provides access to multicast content via autotunneling, using and enhanced version of UMTP (UDP Multicast Tunneling Protocol). XCast and XCast+ offer an explicit multicast service using only unicast routing. The XCast/XCast+ source must know the IP addresses of the all receivers that are included in a list in an extension IP header. ESM (End System Multicast) is a proposal in which all the multicast operations- group management, data routing and packet replication- are implemented by the end system, using only unicast transmissions. HyperCast allows the creation and the maintenance of logical overlay topologies between

applications, thus offering a multicast like service. Two mechanisms are used to create the overlay topology: HyperCube and Delaunay Triangulation.

References: [Blaga 06b, Blaga 06c, Blaga 07b]

3. **Measurement of join latency, control overhead, forwarding delay and jitter for the following multicast routing protocols: DVMRP, PIM-DM and PIM-SM.** A multicast traffic analyzer was implemented based on a capture node, Ethereal/Wireshark tool, a special parser for XML result files, distinct analyzers for each parameter and a graphical interface.

   Main results refer to PIM-DM and PIM-SM in IPv6. In dense mode operation multicast traffic is distributed through flooding in the whole network, thus, in the moment the receiver joins the group, the multicast data could be present on the receiver's link or the designated router's link. In sparse mode operation multicast data first reaches the RP (Rendezvous-Point) encapsulated in PIM Register messages, and only then it is distributed through multicast to the receivers. The control overhead, the forwarding delay and jitter do not show major differences between the analyzed multicast routing protocols.

   The selection of the operation mode, dense or sparse, and thus of the routing protocol is based on the join latency parameter, because the other parameters do not show significant differences between the operation modes. The use of dens mode operation is recommended for delay sensitive applications and sparse mode operation for delay tolerant applications.

   References: [Blaga 04e, Blaga 04f, Blaga 05b, Blaga 06e]

4. **Determination of the effects of bidirectional tunneling in Mobile IPv6,** through the implementation of a test architecture that includes a mobile node MN, a home agent HA and a correspondent node CN. Results show that the values for RTT (Round Trip Time) between the MN and the CN can double if the MN is in the visited network. If the MN, CN and HA are not connected to the same router (most often case in the real world), then RTT can be much higher than the value obtained when the MN is in the home network. This conclusion if important because in the multicast routing for mobile nodes, the group joining process and the data is received through bidirectional tunneling between the HA and the MN. The route optimization mechanism can not be used in this case.

   References: [Blaga 03]

5. **BGP4 exterior routing protocol was studied by a detailed analysis of the finite state machine** (states: Idle, Connect, Active, OpenSent, OpenConfirm, and Established) **using ns-2 simulator**. During normal operation for the BGP connection establishment process the time elapsed in the states Connect, OpenSent and OpenConfirm is approximately two times the link delay. The Established state is the only state in which unicast and multicast routing information can be exchanged, thus the connection must remain in this state as much as possible. The influence on the performance of multicast routing protocols is in this case minimized to the delay of the TCP connection between the two routing domains.

   References: [Katona/Blaga 05]

6. **The performance parameters for AGCS technologies: stress, resource utilization, stretch, time to first packet and control overhead were evaluated.** Using these parameters five proposals: CastGate, XCast, XCast+, ESM and HyperCast, were compared in a test architecture containing a minimum of 17 receiving hosts. The architecture with only 9 receivers does not demonstrate all the possible scenarios. Compared with native multicast the best alternative is XCast+ with network support with a resource usage only 15% higher and the same value for stretch one. Other alternative proposals like the CastGate client, HyperCast and XCast with premature X2U proved to have the same low performance as unicast regarding resource usage. Referring to the stretch parameter the scenarios using XCast/XCast+ with semipermeable tunneling must be avoided. In general as the number of links and/or the number of receiving hosts increases the performance decreases compared to the minimal test architecture configuration.

   References: [Blaga 05b, Blaga 06a, Blaga 06b, Blaga 06c, Blaga 06d, Blaga 07b]

7. **Enhancement of CastGate technology by using the CastGate router together with the PIM-SMv2 multicast routing protocol in IPv4.** The source code written in C++ in Linux was integrated in the existing CastGate implementation. Using the defined AGCS performance parameters show that the proposed enhancement is better than the previous CastGate based solutions. The CastGate router with PIM-SM has a resource usage only 15% higher than native multicast and its location in the domain influences the stretch parameter.

   References: [Blaga 05a, Blaga 05b, Blaga 06a, Blaga 06c, Blaga 06d]

8. **Extension of CastGate technology in order to allow the transmision of IPv6 multicast traffic over IPv4 tunnels.** This was accomplished by modifying the Enhanced UMTP trailer and by introducing new commands and options that permit the IPv6 tunneling negotiation. This contribution does not improve CastGate performance, being an intermediate solution until the generalization of IPv6 multicast.

   References: [Blaga 05b]

9. **Enhancement of XCast/XCast+ technology by using the PIM-SMv2 multicast routing protocol on routers and hosts.** This contribution is based on the fact the use of PIM-SMv2 protocol with CastGate proved to be efficient, thus suggesting the generalization of the concept for other AGSC technologies. Evaluated performances are similar to XCast+ with network support, with the mention that stretch is 33% higher. This increase in stretch is compensated by the ease of deployment for XCast++, as only one device is needed.

   References: [Blaga 06b]

10. **The design and implementation of a new translation mechanism for multicast data and associated SAP/SDP messages.** The proposal is based on the integration of PIM-SM with IGMP (Internet Group Management Protocol) and MLD (Multicast Listener Discovery). The translation is performed on demand only if multicast receivers are present. The novelty refers to the use of PIM-SM in both domains, meaning IPv4 and also IPv6. Previous solutions (UNINETT) only used PIM-SM in the IPv6 domain.

References: [Blaga 07a]

2.1 CONCLUDING REMARKS

The thesis **"CONTRIBUTIONS TO THE ENHANCEMENT OF MULTICAST ROUTING"** is aimed at providing solutions for **the lack of multicast deployment in Internet** (for applications like IPTV, VOD, etc).

The interest for this subject is proven by its presence as a priority in FP7 projects like **4WARD** (**W**ired & **W**ireless **W**orld **W**ide **AR**chitecture and **D**esign for the Future Internet). The aim is the design of a new radical architecture for the future Internet. The following concepts are used: network resource virtualization, architectures with self-management, information-centric communication model that will replace the current host-centric model. The generic path concept will allow multicast communication and will adapt transport functions to the capabilities of the underlying network. Personal involvement in this project permits the use of knowledge obtained in the field of multicasting by contributing to the development future Internet multicast specifications.

The contributions presented in this thesis are valid in the context of the 4WARD project and we can move on from the multicast routing enhancement phase to the phase of routing optimization if new concepts like Cross-Layering are implemented.

2.2 AWARDS

1. Winner of the 5th RoEduNet IEEE Internatinal Conference Student Paper Contest, for the paper: "*Performance Metrics for AGCS Applied to CastGate Technology and Native Multicast"*, Sibiu, 3rd of June 2006.

2. Ericsson awards of Excellence in Telecommunications, for the paper: "*XCast++: Proposed Extension for Explicit Multicast Protocol"*, Bucharest, 30th of June 2006.

2.3 PUBLICATIONS REFERENCED IN THIS THESIS

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[Blaga 04d] - **T. Blaga**, V. Dobrota, **Routing Protocols in IPv4/IPv6 Using Linux**, Proceedings of the IEEE International Conference "Communications 2004", Military Technical Academy, Politehnica University of Bucharest and IEEE Romanian Section Bucharest, 3-4 June, 2004, pp. 453-458, ISBN 973-640-035-2.

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[Blaga 06d] - **T. Blaga**, G. Lazar, B. Moraru, V. Dobrota, **Performance Metrics for AGCS Applied to CastGate Technology and Native Multicast**, Proceedings of the 5th RoEduNet International Conference, Sibiu, June 1-3, 2006, pp. 176-180, ISBN 973-739-277-9.

[Blaga 06e] - **T. Blaga**, I. Trestian, G. Lazar, V. Dobrota, **Performance Evaluation of IP Multicast Routing**, Proceedings of the IEEE International Conference "Communications 2006", Military Technical Academy, Politehnica University of Bucharest and IEEE Romanian Section Bucharest, 8-10 June, 2006, pp. 317-320, ISBN 973-718-479-3.

[Blaga 07a] - **T. Blaga**, F. Szasz, R. Vidrascu, V. Dobrota, **An On-Demand IPv4/IPv6 Multicast Translator**, Proceedings of the 6th RoEduNet International Conference, Craiova, November 23-24, 2007, in curs de publicare.

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2.4 PH.D. REPORTS AND RECHNICAL REPORTS

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2.5 PUBLICATIONS OUT OF THE SCOPE OF THIS THESIS

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