APPLICATION OF MULTICAST TRANSPORT PROTOCOLS IN TELECONTROL

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ABSTRACT

In this paper we propose the use of multicast protocols in telecontrol networks based on IP technology. These protocols add functionality to SCADA systems and are easy to implement. Thus, the implantation of SCADA systems with distributed knowledge in RTUs or the configuration of secondary Control Centers can make the actual systems more safe, efficient, easy and also be more robust to an act of sabotage.

1. INTRODUCTION

Typically, protocols applied in SCADA system are based on architectural models [1], [2], [3] that bind together both the upper layers (usually application layer) and the lower layers (mainly physical and data link layers). In some ways, polling protocols are frequently used at medium access layer (MAC) related very closely to application layer, for instance, whenever the Control Center requests information from an RTU and awaits for its response.

The migration to IP (Internet Protocol) [4] environments, as the telecontrol network links bandwidth is increased, required installing intermediate layers. These layers usually overload the amount of control data to be exchanged (like TCP). The couple TCP (Transmission Control Protocol) over IP has helped the explosion of Internet; TCP/IP is robustness, reliable and very well documented (free RFCs) network architecture.

TCP/IP [5] was designed to communicate processes based on the client and server models (for instance using the socket interfaces). The client and server model doesn’t fit well with the traditional architecture of a SCADA system, where the Control Center should be the server and the RTUs the clients. However, it is the Control Center the one which establishes the connection, because of the polling protocol, dislike in the client and server model where the server is awaiting establishment connection from the clients.

On the one hand the implantation of IP networks, and on the other hand the application of meshed topology (switched networks against broadcast networks), makes possible to allow RTU usually sends information for its owns (without a previous request).

2. UNICAST VS MULTICAST

Almost all data that flows over the IP networks is encapsulated in a unicast datagrams; i. e., the sender identifies the address of an individual receiver of the datagram. Sometimes, it is required to send a datagram to more than one receiver, to a group or receivers or to all the receivers in a network. This is typical of some address learning protocols like ARP [6] (Address Resolution Protocol) and RARP [7] (Reverse Address Resolution Protocol) applied in IP networks. These protocols use the broadcast address to send the reply request packet.

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However, except for the control Internet traffic, all routers usually do not forward the broadcast traffic because it is dangerous to distribute indiscriminately broadcast packet.

Finally, there are many situations where the receiver of a packet is not one station but a group of stations. A multicast address is used in these cases. All devices usually have their unicast IP address and a multicast IP address in the multicast scenarios. When a station sends an IP datagram with an IP multicast address only those stations that belong to the same multicast group (stations that share a multicast address) receive the datagram.

3. WHEN CAN MULTICAST BE USED?

Multicast addressing is an interesting subject but its application has to be appreciated because it increases the complexity of an IP network (multicast routers are required, called mrouters, new protocols have to be configured, etc.).

Multicast must be used when there are a lot of traffic 1:N (one source, many receivers) that saturate the network and performances are in danger. This situation is quite important in centralised systems (or tree systems) where the links close to the central node (or root) suffer more network traffic load (Figure 1).

Telecontrol networks can take advantage of multicast if their IP network infrastructure let them use it as we show next paragraph in telecontrol networks.
4. APPLICATION OF MULTICAST PROTOCOL IN TELECONTROL

The classical topology (broadcast networks over share links based on radio channels, carrier wave, etc.) shown in Figure 2 makes no sense for an SCADA system based in IP technology. Now, a meshed subnetwork replaces the bus topology (switching nodes that interconnect subnetworks via different links) where RTUs and control Center (primary and secondary) connect to it (Figure 3).

However, for operative reasons, this meshed network usually is structured in several subnetworks interconnected via routers (Figure 4).

In this context, there are many application that justify the use of multicast:

a) Multicast traffic generated by the RTUs:

There are many situations where the information sent by a RTU is useful not only for the Control Center but also for other receivers. Thus, if there is a secondary Control Center or a back up Control Center, the RTU can send the information to everyone simultaneously with only a transmission. The possible failures of the Control Center are transparent to RTU with IP multicast.

If datagrams generated by RTUs include multimedia information (audio and/or video), a typical situation nowadays, then the use of multicast is mandatory.
RTUs can also make a backup of their database in the Control Center or in other RTUs applying multicast.

As the level of knowledge in RTUs increased together with the application of expert system technology will let RTUs make decisions on their own (without the supervision of the Control Center) based on the data capture and/or received from other RTUs (specially the ones closest). The role of multicast addressing is determinant in this distributed control.

b) Multicast traffic generated by the Control Center.

The use of multicast addressing is quite useful in the packets generated by the Control Center. Let us show some examples:

- The RTUs’ polling cycles (RTUs are polled individually in classical configuration) can be replaced by multicast reply request.
- The distributed database updates of the different RTUs can be made once with multicast traffic.
- Multicast traffic can distribute data from the Control Center to other Control Centers or Back up Control Centres.
- The synchronization of the RTUs can be replaced by a multicast request.
- Multicast traffic can emulate, in telecontrol networks, a multiconference session via IP (for maintenance or management purposes, etc).
- Etc.

5. IMPLEMENTATION

The reliability or not of a multicast implementation depends on the kind of application. Let us show some situations:

- Schemes based on UDP [8] (User Datagram Protocol) over IP multicast (RFC 1112) [9] are usually used both in multimedia application like multidiffusion video or real time application, where the main parameter is the reply time.

These solutions, that are easy to implement, have many inconveniences like the possible duplicated or missed datagram and the absence of congestion control mechanism. The failures are detected and rejected but not corrected in these cases.

The typical implementation are usually complemented with the IGMP (Internet Group Management Protocol, RFC 2236) [10] protocol and DVMRP (Distance Vector Multicast Routing Protocol, RFC 1075) [11] protocol. The stations notify the multicast group to the multicast routers (mrouters) by IGMP and the mrouters used the DVMRP as the multicast routing protocol.

- The UDP/IP-multicast configuration is not adequate for applications where the reliability is required. UDP is replaced by Reliable Multicast Transport Protocol (RMTP) in these cases. For instance, the possible transmission errors must be corrected in the database distribution of the RTUs.

Nowadays there are no RFCs that describe any RMTP protocol, only there is an Internet draft published in 1998 that describes RTMP-II. There only are some recommendations like RFC 2357 [12] that lays out the requirements for reliable multicast protocols or RFC 3048 [13] that describes a framework for the standardisation of bulk-data reliable multicast transport.

RTMP-II [14] is a reliable multicast protocol, designed to send reliably and efficiently data from a few senders to large groups of simultaneous recipients. However its complexity does not justify, sometimes, its application to SCADA systems, where there is a commitment between reliability and response time.

We are developing a reliable multicast transport protocol that includes the group management with different level of hierarchy, but that supposes a really simplification from the RTMP-II Internet draft. This protocol, called NRMTP (New RMTP) is in its final developing phase and is in the field trial phase.

6. CONCLUSION

IP Multicast is a technology that is still developing nowadays. There are many scenarios where IP multicast performance is better than IP Unicast is, for instance when there is a source generating traffic and multiple recipients receiving it.

The behaviour of telecontrol networks based on IP technology is not different and the application of multicast technology is sometimes justified. Some examples are the reduction of polling cycles or the reception of data from RTUs by not only for the Control Center but also for other receivers.
Depending on the reliability needs, reliable or not multicast transport protocols are applied. The UDP protocol, over IP multicast with IGMP protocol and DVMRP protocol, is used if the errors in delivery are not the main factor. There are many reliable multicast protocols but no of them are RFCs. The most popular is RTMP-II but it is so complex that its application is not justified in SCADA systems.

NRMTP is a reliable multicast transport protocol designed to cover SCADA systems needs. Now it is in its final phase and the field trial let us know the robustness of its application in telecontrol IP networks.

7. REFERENCES


