Optimal Level of Hierarchy for Multicast in IP Networks

Milan Berka,

GTS NOVERA a.s, Vystaviste 1, Brno, Czech Republic

Summary
This annotation deals with RTP and RTPC protocols facilities in large numbers of multimedia broadcast's clients via multicast in IP networks. First this annotation describes problems of large number clients and problems of protocol defined from RFC 1350 and 135; then feasible solutions are suggested. Simulation algorithm results are presented as well as analytical problem solving; it contains also discussion about analytical solution availability. Annotation connects to results of research work in project AV ČR T3 0171 05 08 „Optimization methods for multicast in IP networks"

Key words:
Optimalization, multicast, RTP, RTPC, hierarchy

Introduction

Objectives and needs

Many studies and analytical documents describe advantages and new technologies facilities in range of multimedia transmission. Cost saving of assorted conferences and meetings are often evaluated there (in case that they are provided in multimedia way). These transmissions are not so often as teleconferences (computer conferencing). The main target (application of these technologies) should be saving of time, saving of traveling expenses, higher efficiency of meetings, educations and so on.

Present time

Nowadays the digital television, interactive television and broadcast through the Internet are pretty much discussed, analogous to VOIP, teleconferences and others. Although these technologies are often discussed, there are few of practical applications. Only experimental network make testing of these technologies possible.

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Future

It could be expected; that Internet and private network development wend the same way as mobile networks. Private network has better position in term of its development, because they are limited and can have only one network management policy. The situation is more complicated in public network. Integration of these technologies into providing portfolio of services depends on the number of customers interested in these kinds of services and their willingness to pay.

Using of these technologies could be influenced for example saving cost requirements on time, administration, telephone traffic, and so on.

Problems

Operator's network is not configured for usage of multicast (perhaps except of network CESNET2). Definition of protocols used for multimedia transmissions is not solved very well for large numbers of clients (especially RTP/RTCP protocols over UDP). UNICAST methods used are limited by bandwidth of backbone network. It could be expected, that these problems should be solved by steps.

Possibly solution

The whole infrastructure could be paralyzed by multimedia broadcast, that's why it's understandable, that unicast shouldn't be used and something else should be used. Large discussion has run on Internet about this theme in article of M.Krska.

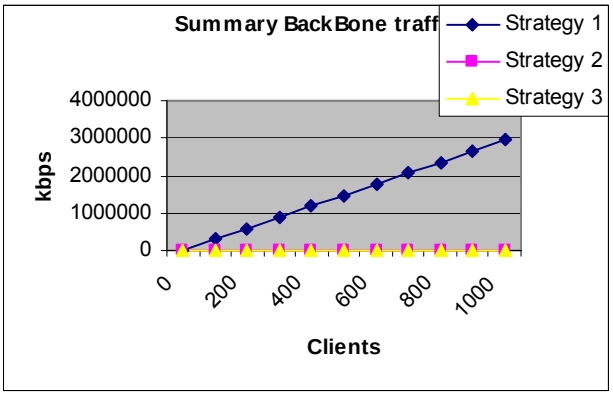
By contrast to Michal Krska our assumption is that signal dissemination has been solved and doesn't mean the main problem. Actually the adequate solution is not implemented into network, but this is not theoretical problem.

SSM - Specific Source Multicast is the solution, but only in the range of data content dissemination. Other problems exist here. These problems consist in protocols RTP/RTPC (where from echoing of protocol providing information about quality of signal dissemination) it follows that according to formula from dle RFC 1350 a 135, and interval of report is directly proportional to number of clients. For example this interval is 33 minutes for 100 000 viewers (this number of viewers is usually higher for television broadcast). This response is practically unavailable.

Several solutions feasible exist in this area. The first is modification of signal dissemination upon echoing data concentration on network elements. Some crags of this solution consist in problem, that network element has to solve many tasks, which doesn't know; these algorithms should be implemented by producer. This alternative is ineffective in term of from short – time view.

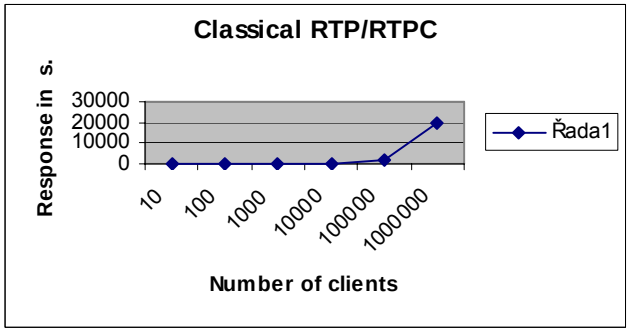
The second alternative is that some of clients take the role of echoing data concentrator. Something like reverse situation toward CDN technology evolves in that case. This situation requires minor correction of protocol, but theoretical response speed comes down from above mentioned 33 minutes to ca 30 seconds. The difference is evident (from 5 hours to 50 seconds for 1 000 000 clients). Nowadays technology modeling is being in progress

Development of increase backbone capacity need shows the following graph. It is obvious, that the need of increase backbone capacity is minimal for SSM solution by loading of last miles of clients. Upward sloping curve correspond to unicast.



The following two graphs compare interval of responses for classical RTP/RTPC with aggregation method in two hierarchic levels. There is a question about adequate number of hierarchic levels for optimal response; this question is object of theoretical analysis. The number of 1 000 000 clients seems to be in two hierarchic levels as sufficient in numbers. Classical scheme from RFC 1350, 1351 size up consequently:

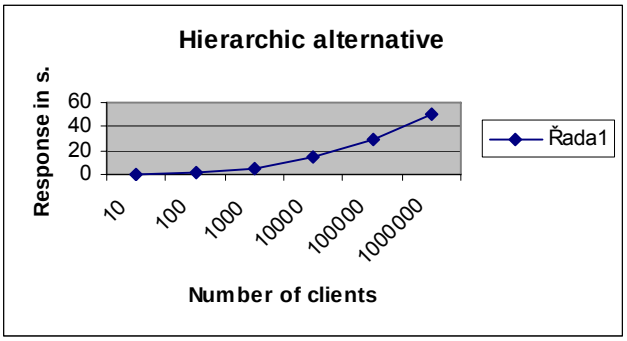
Number of clients	Response in seconds	Response in minutes	Response in hours
10	0,196267	0	0
100	1,962667	0	0
1 000	19,62667	0	0
10 000	196,2667	3	0
100 000	1962,667	33	1
1 000 000	19 626,67	327	5



The situation is much effective by using hierarchic levels. The following table represents only two hierarchic levels. Needed hierarchy could be designed over required response in this structure. Although in case, we don't aim to minimize response time, the situation is more optimistic.

Number of clients	Number of nodes	Number of respondents in group	Response in seconds
10	1	10	0,19
100	10	10	1,96
1 000	31	32	5
10 000	255	39	15
100 000	510	196	30
1 000 000	1019	981	50

This situation is similar to CDN technology analogous to reverse form. Nodes don't divide data stream, but conversely integrate. One can understand as conversely P2P.



In conclusion, multicast alone is not able to solve problem of large numbers of multimedia broadcast respondents. New methods in this area are similar to problem solving methods used in neuron network.

Analytical solution

Except network simulation, it is possible to describe many parameters of protocol RTP/RTPC in mathematical form and reach the similar results.

$$NumberOfClients = \frac{0.75 * Speed * ResponseTime}{PacketSize};$$

Response time could be figured from this formula, and we can receive the same value as was indicated in previous table.

$$10^5 = \frac{0.75 * 5 * 10^4 * X}{736}; \; X = 1963 \text{ seconds} = 33 \text{ minutes};$$

Theoretical solution is (above-mentioned) hierarchy using. Some thesis will be accepted for simplification of solution. Information will be sent to server from not all clients, but they will be conjoined by groups. Specialized clients will exist for consolidation of information; this information will be sent by these clients further.

We will suppose, that

1. Groups have the same number of clients
2. Responses are the same for all groups and all clients
3. Length of protocol RTPC packets are the same
4. Hierarchy tree is smooth

The following formula is valid in that case

$$NumberOfClients = \left(\frac{0.75 * Speed}{PacketSIze}\right)^i * X^i;$$

Then the response time of one group of clients could be figured in the following form

$$X_i = \sqrt[i]{NumberOfClients} * \frac{736}{5 * 10^4 * 0.75};$$

And then the total response time of all clients towards central server will be figured in the following form

$$X = \left\{ i * \sqrt[i]{NumberOfClients} * \frac{736}{5 * 10^4 * 0.75} \right\};$$

The problem of this formula is that it contains parameter "i" responding to hierarchic level. Then it is logical to find out optimal hierarchic level for specific fixed number of clients, to find out the value of optimal "i"and "i_0"

$$i_0 = Argmin \left\{ i * \sqrt[i]{NumberOfClients} * \frac{736}{5 * 10^4 * 0.75} \right\};$$

If we don't pay any attention to constants without hold on argument minimum value, then actually we are finding the minimum of parametrical function

$$f(i) = i * \sqrt[i]{n};$$

And the solution is value

$$i_0 = \ln(n);$$

Optimal hierarchic levels are presented in the following table:

Number of clients	Optimal hierarchic level
10	2
100	5
1000	7
10000	9
100000	12
1000000	14

It is interesting finding, how the hierarchic level changes size of response time, and we could evaluate, if the

management of hierarchic levels is effective in area of protocol's response.

This situation describes the following table

hierarchy	10	100	1000	10000	100000	1000000
1	0.2	1.96	19.63	196.27	1962.67	19626.67
2	**0.12**	0.39	1.24	3.93	12.41	39.25
3	0.13	0.27	0.59	1.27	2.73	5.89
4	0.14	0.25	0.44	0.79	1.4	2.48
5	0.16	**0.25**	0.39	0.62	0.98	1.56
6	0.17	0.25	0.37	0.55	0.8	1.18
7	0.19	0.27	**0.37**	0.51	0.71	0.99
8	0.21	0.28	0.37	0.5	0.66	0.88
9	0.23	0.29	0.38	**0.49**	0.63	0.82
10	0.25	0.31	0.39	0.49	0.62	0.78
11	X	0.33	0.4	0.5	0.61	0.76
12	X	0.35	0.42	0.51	**0.61**	0.74
13	X	0.36	0.43	0.52	0.62	0.74
14	X	0.38	0.45	0.53	0.63	**0.74**
15	X	0.4	0.47	0.54	0.63	0.74

Minimum is indicating by bold face and adequate values are indicating by grey background. Minimums are very shallow curvature to reach them is difficult in term of the whole hierarchy structure management. We are recommended to use low level of hierarchy structure.

References

[1] http://home.eunet.cz/berka/

Milan Berka he finished the Faculty of Cybernetic and Computer Science of the Lomonosov Moscow State University in year 1979 years and in 1982 he obtained the PhD degree. He became an assistant lecturer at chair of mathematics of the Faculty of Civil Engineering, Brno Technical University in 1982. In 1983 he obtained a degree of RNDr. from the Faculty of Mathematics and Physics, Charles's University, Prague. In 1989 he was appointed a lecturer at the Professor and at the chair of mathematics and descriptive geometry of the Faculty of Civil Engineering, Brno Technical University. In 1990 he was accepted to the chair of Computer Science. From 1991 to 1997 he was of the head of the Institute of CAD and Computer Science.

In 1997, after sex years in this position, he was accepted as IT Manager of private company Internet CZ, EUnet Inc., KPNQwest and GTS. In this time he works as IT Security Manager.

Research interests: Information Society, general impact of Informatics, Computer Science and Operations Research, logic programming and specification-based programming methods, electronic typesetting, Computer Security.

Publication activity: 5 books, more than 40 papers in journals, conference proceedings, and research reports; over 100 reviews in review journals.