pared to the 16-state. However, the tradeoff in implementation complexity is too high. The last column of Table 1 shows the relative complexity of various M-D TCM codes. Using the Viterbi algorithm, 4D 2/3 16-state TCM does not require more computational steps than the 2D version; its computational complexity is still at the same level because of their identical trellis structure. Similarly, it is possible to use 8D or even higher dimensional TCM. The only drawback is that low transmission delay and relatively flat channel characteristics are required. However, when the number of states increases, the computational complexity increases proportionally together with a simultaneous expansion of the cache memory size. Hence for a cost-effective solution, a 4D or 8D TCM structure with < 64 states is recommended.

Conclusion: We have compared the applications of different multidimensional TCM schemes in an ADSL channel to improve the system performance and presented a practical measuring criterion with which to evaluate them, especially for specific multidimensional approaches. Simulation results show that the performance is more sensitive to the code dimension than to the code rate, i.e. increasing the dimensions of TCM can improve the BER performance much more than is possible by changing the code rate. Furthermore, increasing the number of states improves the performance marginally, but results in greatly increased complexity of the decoding procedure.

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Non-core based shared tree architecture for IP multicasting

Seok J. Koh, Myung K. Shin, Jong H. Yi, Jin H. Hahm and Chee H. Park

The core-based tree (CBT) has three main limitations. The selection of the core node is difficult and the traffic is concentrated near the core router. Also the CBT does not consider an optimisation of network resource utilisation. In the proposed non-core based tree (NCBT), an on-tree node is assigned to each incoming member for multicasting such that the maximum end-to-end delay and the tree costs are jointly minimised.

Introduction: The core-based tree (CBT) is a shared tree architecture using the explicit join mechanism, which is employed by the CBT protocol [1, 2] and PIM-SM [3] protocol. In terms of scalability, the CBT has an advantage over the source-based tree architecture, which is used in the MOSPF [4] and the DVMRP [5].

However, the CBT has three main limitations. First, optimal core node selection is very difficult since the location of group members is not known *a priori*, in particular, in real-time applications. In fact, the core node selection problem is a controversial issue in the study of inter-domain multicast routing. The second drawback is the traffic concentration near the core router. Most multicast traffic is concentrated at the links near the core router since all group members send the multicast data toward the core router. Finally, the CBT does not optimise the utilisation of network resources on the tree.

In this Letter, we propose a non-core based tree (NCBT) multicast routing architecture. In the proposed architecture, no core node is used. Instead, a multicast node among on-tree nodes is assigned to each new incoming member. This multicast node is selected such that the length of the path from the incoming user to a multicast node and the maximum end-to-end delay on the tree are jointly minimised. Thus the proposed NCBT architecture can overcome the drawbacks of the CBT. First, core node selection is not required since multicast nodes are assigned to each new incoming member. In the NCBT, traffic is also distributed over several on-tree nodes. In particular, the NCBT provides an optimal tree in terms of network resources and delay performance, as shown in the experimental results.

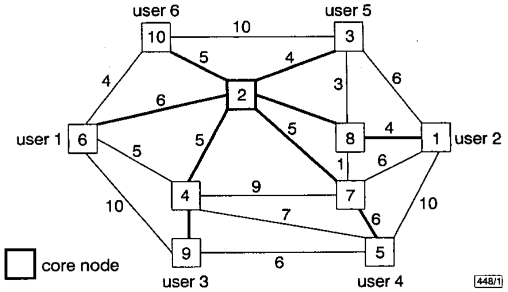

Fig. 1 *Core based tree*

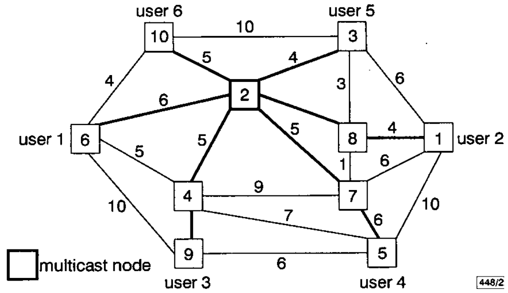

Fig. 2 *Non-core based tree*

Non-core based tree multicast routing architecture: Fig. 1 illustrates an example of the CBT in a network with 10 nodes. In the Figure each number on the link represents the link cost or distance between two nodes. In the network, node 2 represents the core node for the multicast group. The CBT is constructed by finding the shortest path between all members and the core node.

Fig. 2 illustrates the proposed NCBT architecture. In the network, no core nodes are assigned. In the Figure, user 1 opens a multicast session at node 6. When user 2 arrives at the network, the shortest path from node 1 to node 6 is obtained. Then the current multicast tree consists of nodes 1, 8, 2 and 6, as shown in the Figure. Consider user 3 who arrives at access node 9. The user selects a multicast node among the current on-tree nodes, nodes 1, 8, 2 and 6, such that the sum of the length of path from node 9 to the multicast node and the maximum end-to-end delay is minimised. In the Figure, node 2 is selected as the multicast node of user 3. In this case, the length of the shortest path between node 9 and 2 is 5 + 3 = 8, and the maximum delay of the tree is 17, which represents the path length of the path between two nodes 9 and 1. In a similar way, users 4, 5 and 6 select nodes 8, 8 and 2 as multicast nodes, respectively.

Performance comparisons: To compare the performance of those two algorithms, we employ two test networks with 30 and 50 nodes. For each network, it is assumed that each user randomly arrives at the network. In the network, the link cost is randomly assigned as an integer number that is uniformly generated in the range 1 – 10. All experiments presented in this Letter were performed on an HP Workstation, using C language.

To evaluate the performance of two algorithms, we calculated the following two metrics.

(1) tree costs, which represents the sum of link costs for the resulting tree

(2) maximum delay, which represents the maximum value of all end-to-end delays in the tree.

Note that the tree cost represents the link resources required for multicast routing, and the maximum end-to-end delay represents the quality of service for the multicast users.

Compared to the CBT, the proposed NCBT architecture has a critical advantage in that the core node selection problem does not need to be addressed. It is difficult to select an optimal core node since the locations of group members are not known *a priori* for most real-time applications. In addition, the performance of the CBT strongly depends on the selected core node.

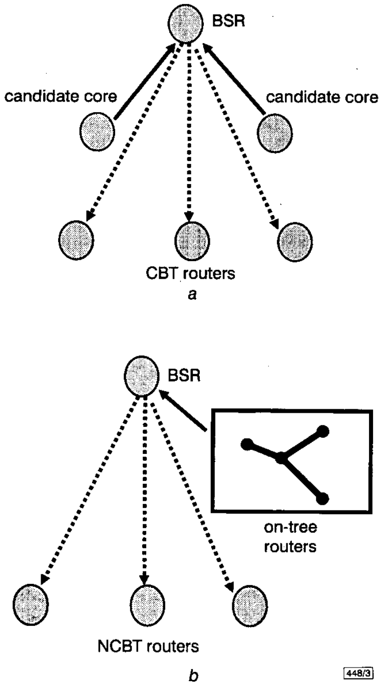

Fig. 3 *Implementation requirements*

a CBT case
b NCBT case

Table 1 shows the performance of the CBT and NCBT for the same arrival patterns of group members. In the implementations of the CBT, the maximum and minimum values of two measures were obtained by employing all network nodes as a core node in a one by one manner. From the Table 1 it is clear that the performance of the CBT varies by the selected core node. On the other hand, the performance of the proposed NCBT algorithm is better than or equal to that of the CBT. In particular, in terms of tree costs, the NCBT provides better performance than the minimum of the CBT.

Table 1: Comparison of CBT and NCBT

	Tree cost			Maximum delay		
Number of nodes	CBT (max)	CBT (min)	NCBT	CBT (max)	CBT (min)	NCBT
30	91	63	63	22	17	17
50	127	97	92	24	18	18

Conclusions: The proposed NCBT is a shared tree architecture using the explicit join mechanism, which is similar to the CBT architecture. In the CBT, a core node is pre-designated *a priori* for all group members, while the NCBT adaptively selects a multicast node for each new incoming user. The proposed NCBT provides an optimal tree in terms of tree costs and maximum delay. In the NCBT, in particular, core node selection is not required and multicast traffic is distributed over all tree nodes.

In implementing the NCBT, however, the network requires an additional capability. All nodes in the network should maintain the current tree information, since one of the current on-tree nodes is selected for each new incoming member. On the other hand, in the CBT approach, all nodes in the network must keep the information of the core node location. To do this, the bootstrap router (BSR) broadcasts the information of candidate core nodes onto all CBT routers, as shown in Fig. 3*a*. Similarly, in the NCBT case, the information of on-tree nodes is broadcast to all routers, as shown in Fig. 3*b*. Note that the overhead required for the tree building and maintenance is nearly same for both approaches.

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Pulse compression filter generating optimal uniform range sidelobe level

W.K. Lee and H.D. Griffiths

A uniform sidelobe level represents an optimum performance criterion in the design of pulse compression waveforms. A new form of pulse compression filter for polyphase codes is presented which generates a flat uniform sidelobe pattern similar to those obtainable from Barker codes. The sidelobe levels are decided solely by the length of the phase codes, which can be set arbitrarily. Their use involves a small loss and degradation in range resolution, but excellent Doppler tolerance.

Introduction: Sidelobe suppression has always been one of the major concerns in designing pulse compression waveforms and filters in radar and sonar systems [1]. Phase coded waveforms tend to be favoured when low sidelobe levels are desired. In addition, compatibility with digital generation and compression makes their use more attractive [2]. Barker codes are known to give good performance; they achieve unit peak sidelobe level throughout the entire sidelobe regions, which is why they are known as 'perfect' codes. However, their limited code length and high Doppler shift sensitivity (a property shared by most other phase codes) restrict their applications. A uniform sidelobe level represents an optimum performance criterion. Using a modified polyphase code derived directly from linear FM, we introduce a new type of compression filter and explain how it achieves this optimal uniform sidelobe performance, with excellent Doppler tolerance.

Mathematical derivation and implementation: Let $S(t)$ be a polyphase code sequence directly derived from a conventional linear FM signal. The function $S(t)$ may be expressed as

$$S(t) = \sum_{p=0}^{N} \exp\left(j\frac{\pi}{N}p^2\right) U\left[\frac{t-(p+1/2)t_b}{t_b}\right] \qquad (1)$$

where $U(t) = 1$ for $|t| < \frac{1}{2}$ and zero elsewhere. t_b is the time duration of one element of the code sequence. Basically $S(t)$ is identical to the P3 code in [4] apart from one new term added at the end of the sequence to make it perfectly symmetrical. When the pulse compression ratio is sufficiently high, it can be shown that the