Chapter 8

Future Work

8.1 Change of Adapters

The intelligent selection of adapters will prove to be a promising enhancement for the planning procedures described in the previous sections. We believe that a variety of adapters will be offered by the adapter designer community to handle most network problems. Specifics of the adapter or the experience of the planner with the adapters will influence the selection process. If, for some reason, the experience with a set of particular adapters is not positive, the planner will be able to change those adapters.

8.1.1 Planning fails because no feasible or consistent plan is found

The process of planning can fail if no feasible plan is found for the particular network circumstances with the set of adapters selected at the beginning. The idea is to replace the adapters that most probably caused the plan calculation failure. These adapters have undesirable side effects or are resource-costly. The planner replaces these adapters with other adapters that could be better-suited for the network conditions and recalculates the plan. For example, the planner can choose a compressor that has lower compressing power but is also less resource-costly.

8.1.2 Connection failure

A connection can fail for the following reasons:

- A Panda node failed (but Internet delivery still works).
- The adapter(s) is broken.

In these cases the source node will discover that the destination is not receiving the data packets or cannot interpret them. Conductor [Yarvis00] uses split-TCP protocol for packet delivery. The destination can send acknowledgements to the source upon the successful arrival of the UDP packets.

In the first case, the plan should be recalculated without using the lost node. The planning data must be restored on the nodes adjacent to the failed Panda node and used for plan recalculation. The failure of the Panda node could be caused by different reasons, including malicious adapters. During replanning, the planner should carefully consider which adapters are used in the plan, especially if it lacks experience with some of the possible choices.

In the second case, when the destination node reports that it cannot interpret the data received, the planner should detect which adapter failed and replace it. The detection of the exact adapter that failed may be a difficult problem unless the data records adapter identity stamps after the successful processing. However, identity stamps do not guarantee the right answer because the adapter can be designed so that even if processing is not done correctly, the records are accurately added. Therefore, the detection of the failed adapter can be a problem that cannot be solved without intelligence in the planner. The planner will keep the track of the successful and failed connections, learn about adapter packages, and develop adapter profiles to determine which adapter was responsible for the failure. The problem becomes more difficult if an adapter fails because of malicious intent. This adapter can destroy identity records or forge them. In the latter case, digital signatures may be necessary to prevent forgery.

Every replanning process should be accompanied by an intelligent procedure that determines the cause of the failure. If a replanning is caused by a plan calculation, ONA failure, or adapter failure, the reselection of adapters requires more accuracy.

8.2 Planning for Multicast Connections

Planning for multicast connections is very complicated, especially in an environment where any member can freely join a session or leave it. Joining and leaving by multicast session members causes a replanning of the whole tree if the search for an effective plan is pursued. A change of the source node in the multicast tree also may cause complete multicast tree replanning. Whole multicast tree replanning is an expensive procedure because planning data collection and plan deployment can cause serious and time-costly traffic within the whole tree. If we try to keep the replanning as local as possible, we probably cannot claim that the plan is effective. These issues require additional research.

8.3 ONA Resource Management

Resource management is being heavily studied by the ONA community. An RSVP-like protocol was developed for ONA environments [Braden01] and [Bush99].

However, the issue of resource management for planning has not yet been addressed. The conditions of a network can change drastically between the moment when planning data is collected and the moment when a plan is calculated and delivered to the nodes. These changes can make a plan obsolete because it was obviously calculated for different network conditions. At the same time, it is hard to reserve resources before the plan is calculated. We could ask nodes that report the planning data to reject any resource requests for some period until a plan is produced that meets the actual resource needs. In this case, we can face situations where all network resources are frozen for some time and planning data gathering fails even if these resources are not be used for any actual connection. However, incremental planning helps here because the connection can begin before the central planning is completed. The planner can afford to make a proper reservation for the resources, wait until they become available and then use them for the central plan. Incremental planning does not depend as much on any reservation mechanism, because local planning occurs almost instantly. Additionally, one of two related nodes is doing the planning, so it is aware of half or more than a half of the changes that occur.

Resource management for planning process is also the area that requires future research.

8.4 Secure Planning Protocol

The design of a secure planning protocol was presented in Chapter 4. We would like to implement this protocol in a real system, but we expect that the security of the planning protocol will be a heavy burden for real-time data streams. However, the real price of security needs much more investigation.

8.5 Alternative Path Planning

Active networks open a huge opportunity for the resolution of connection problems using alternative path planning. For example, alternative path planning can help an ONA connection avoid a congested link or pass through parts of the network that have more network resources available.

In the case of a multicast tree, alternative path planning will allow creation of an alternative branch of the tree with different user application preferences or format requirements.

If user data must be delivered by more than one path to the destination to ensure delivery, an ONA alternative planning procedure can find alternative disjoint paths. Together with the adaptation planning discussed in this dissertation earlier, alternative path planning can improve the QoS provided by ONA.

8.6 Other Communication/Distributed Systems Can Benefit from Automated Planning

Automated planning can provide benefits for many kinds of distributed ONA (such as Conductor discussed in previous sections).

However, distributed ONA is not only the place where planning can be used. We believe that even end-to-end ONA that provides deployable components to distributed systems (such as Rover, CORBA, or Enterprise JavaBeans) can benefit from this work. These distributed systems can use deployable adapters to improve their QoS over the network. Even if no problem exists concerning the location of the adapters (where just two sites are involved in the connection) the problem of adapter order still remains. The order of various adapters with various properties can be solved with the components of the planner discussed earlier in Section 5.1.3.