ESD5 – Fall 2024
Lecture Notes – Lecture 7

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September 23, 2024

Example 1 – Packet Exchange Over Reliable and Unreliable Services

Figs. 1 and 2 illustrate the packet exchange between Zoya and Yoshi. Here, we abstract the communication layers into Higher Layer (HL) and Lower Layer (LL). In this example, we will closely look at the behavior with respect to the layer when we consider the reliable service and unreliable service for the lower layer. Through this example, we will learn the concepts of layering more deeply.

Let us first take a look at the example of Fig. 1, which corresponds to the case where LL provides a **reliable** service. In this case, Zoya's HL just passes the data to the LL. Then, now it is the job of Zoya and Yoshi's LLs to reliably deliver the packet. To this end, Zoya's LL adds

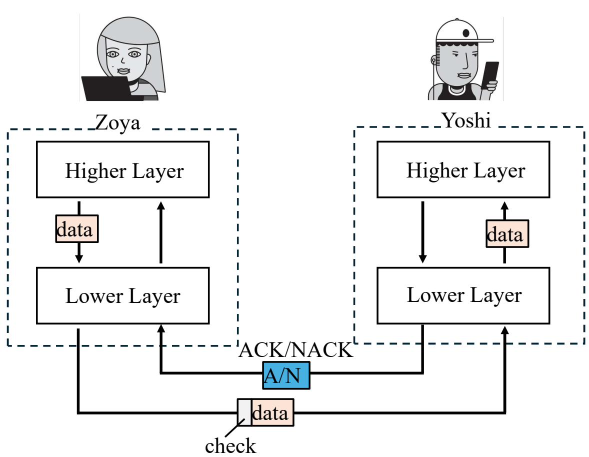

Figure 1: Packet exchange when the LL black box provides a reliable service.

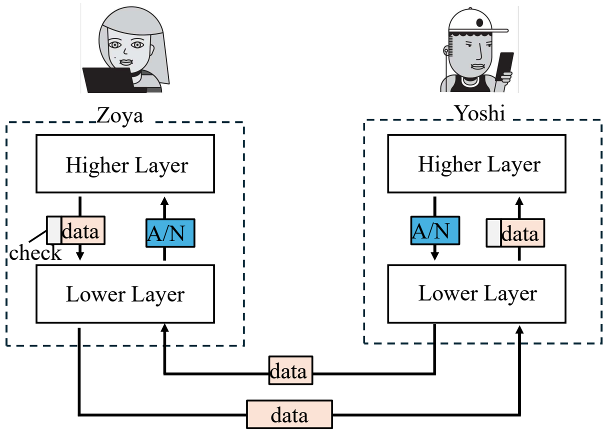

Figure 2: Packet exchange when the LL black box provides an unreliable service.

integrity check information, as shown in Fig. 1. This enables LL to implement the *Automatic Repeat Request* (ARQ) protocol (*cf.* Lecture Notes 5). This can be realized as follows. Yoshi's LL, which, in this case, corresponds to the receiver module, can verify whether it successfully receives the packet from Zoya. If the packet has been correctly received, Yoshi's LL sends an *acknowledgment* (ACK); otherwise, it sends a *negative acknowledgment* (NACK), as in Fig. 1. After receiving the ACK, Zoya's LL can inform Zoya's HL whether the packet has been delivered successfully. On the other hand, if it receives a NACK, Zoya's LL can try to resend the packet several times until it receives an ACK, following the ARQ protocol. Notice that, in practice, as we have studied in Problem 4 of Problem Set 1, we can set the maximum number of retransmissions, say, K retransmissions. If the number of retransmissions reaches the maximum number, then Zoya's LL notifies the failure of data transmission to Zoya's HL.

Next, let us consider the scenario in Fig. 2, in which Zoya's HL needs to use the LL providing an **unreliable** service. Here, unreliable means that Zoya's LL does not present a method to verify whether the transmission was successful, nor a retransmission mechanism. This requires Zoya's HL to add the integrity check information in the packet and handle the acknowledgment process itself. Note that, different from the communication through a reliable service (Fig. 1), in the unreliable case, the LL does not add the integrity check information, as can be seen in Fig. 2. Thanks to the encapsulation, the LL treats the packet as normal data instead of control information. Specifically, Yoshi's LL passes the received packet to the HL without conducting an integrity check. Also, the acknowledgment information will be produced by Yoshi's HL, which is then supplied to its LL. This information can only be decoded by Zoya's HL, as shown in Fig. 2.

Example 2 – Single Point of Failute

In this lecture, we have seen a variety of topologies for communication networks. In this example, we will take a look at the importance of topology while considering its specific

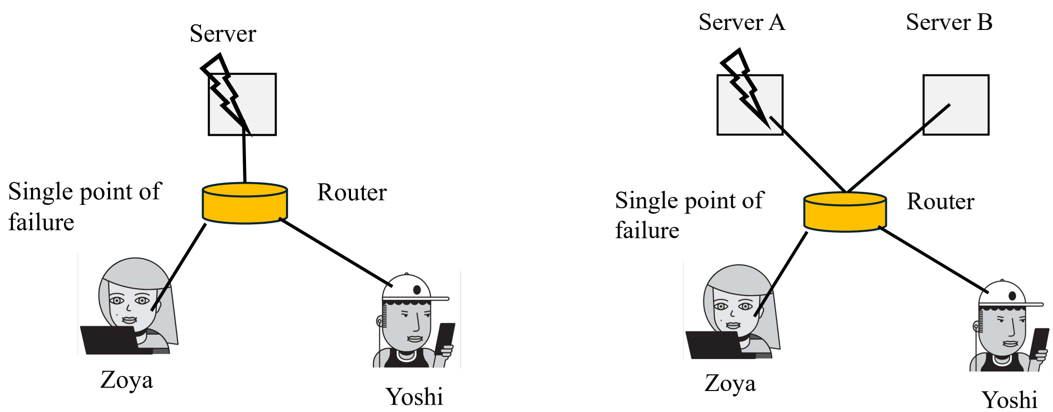

Figure 3: Network topologies to demonstrate the concept of Single Point of Failure.

usage. Let us consider a case where we want to design a network to connect multiple users to a server through the router. In this process, it is important to design a robust system that does not contain any *Single Point Of Failure* (SPOF). A SPOF is a component whose failures are capable of stopping entire systems that are supported by it. To illustrate this notion, let us take a look at the left side of Fig. 3, which represents an example of SPOF. In this example, we consider star topology networks, which are simple to design. However, we can see that this is not resilient to SPOFs, as the failure of the server directly causes service disruption for Zoya, Yoshi, and others who become incapable of obtaining data from the server. How can we realize the robustness in terms of topology? The key to solving this issue is redundancy.

The right side of Fig. 3 shows an example of resilient topology, where Zoya and Yoshi have a topological connection through the router to Server B, which is the duplicate server of A. In this example, as the router is connected to two servers, if one of the servers fails, users like Zoya and Yoshi can obtain the same information from the duplicate server. However, we can see that this requires periodic synchronization, which could be a maintenance cost. You may notice that, with this topology, we solved the problem of SPOF related to the server, but there is still an important SPOF related to the communication between the nodes. In this case, an improved version of our topology could contain one more router to connect Zoya and Yoshi to Servers A and B.

Example 3 – Network Topology for a Rural Community

Imagine you are the engineer in charge of planning the implementation of a new communication service for a rural community. Your goal is to provide them with connectivity service at a fair cost. Considering the characteristics and required infrastructure of different topologies of wired and wireless communications networks, what would be a good option in this case? The answer to this question is not simple, and a definite solution can be reached only with knowledge of more information. For instance, the difficulty of deploying specific

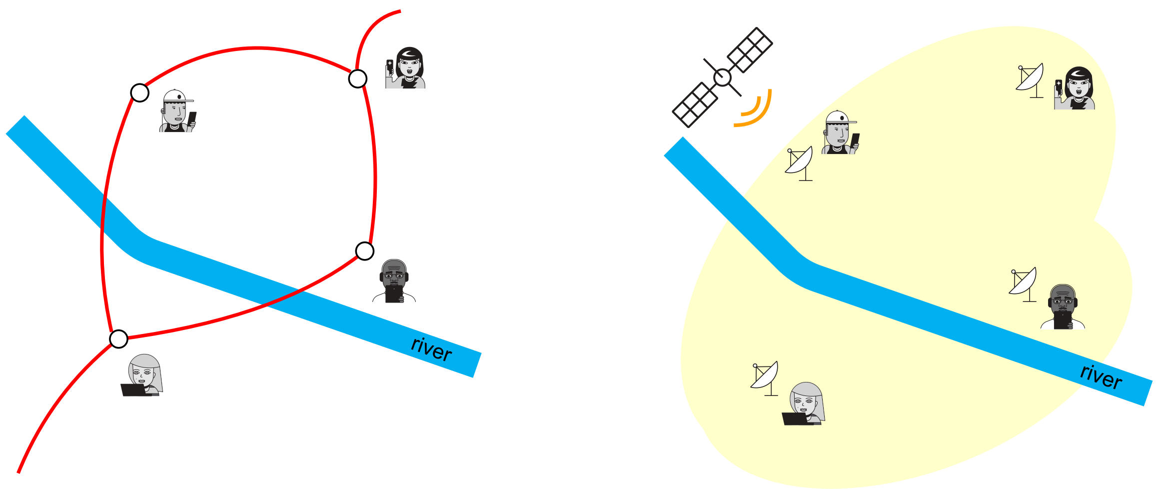

Figure 4: Examples of network topology to provide communication services for the rural community. (Left) Topology based on communication via optical fiber cables. (Right) Topology based on satellite communication.

infrastructure depends on information about the characteristics of the terrain. Moreover, from an economic perspective, the number of connection points to be installed relies on the potential growth of the service demand in the long term. Despite the need for additional information, if we focus only on the area size to be covered and the number of customers, we can analyze the benefits and drawbacks of two topologies, one with optical fiber cables and another based on satellite communication. Fig. 4 depicts how the two topologies would look in our scenario. Recall that, as we are talking about a rural community, the service must connect a few customers spread over a huge area. Accordingly, the communication system will reach a low throughput per area, indicating that our topology should focus on increased coverage instead of high throughput.

Optical Fiber Network. The optical fiber can deliver high-speed communication due to the large bandwidth available. In this type of network, the customer must have an Optical Network Terminal (ONT) on site connected to a Point of Presence (PoP) through cables. The necessity of cable infrastructure can make this network expensive for rural areas, as the installation depends on the terrain and rights of way. Notice that the cables must reach all the customers, so the infrastructure must be changed when a new customer signs up for the communication service.

Satellite Network. Satellite communication has the benefit of providing connectivity to large areas without the need for expensive cable infrastructure on the customer side. This makes such a network solution the most suitable for implementing a communication service in our rural community. To connect to the network, the customers can use a Very-Small Aperture Terminal (VSAT), which is equipped with an antenna capable of transmitting and receiving radio signals to and from the satellites. In this case, the addition of a new customer means the connection of one more VSAT, not requiring infrastructure changes as long as the satellites have available capacity. Despite being high, the cost of deploying satellites has decreased significantly in the last decade, mainly due to the possibility of deploying many devices with a single launch. Furthermore, the satellites present a short deployment time compared to the construction of cable infrastructure over large areas.