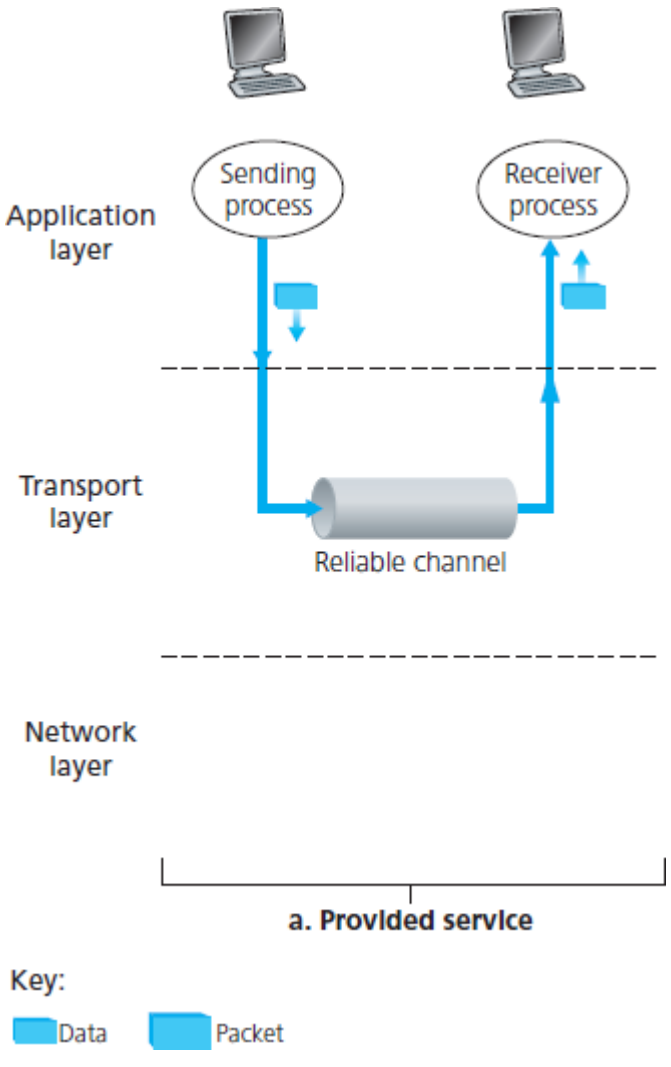


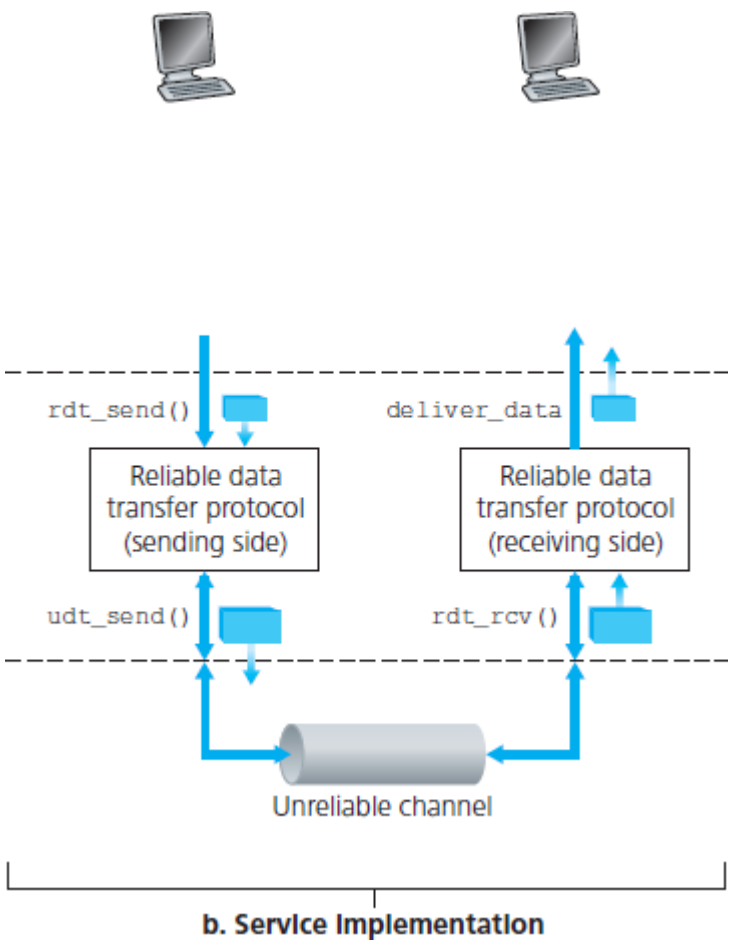


Figure 3.8 Reliable data transfer: Service model and service implementation

needed when the underlying channel can corrupt bits or lose entire packets. One assumption we'll adopt throughout our discussion here is that packets will be delivered in the order in which they were sent, with some packets possibly being lost; that is, the underlying channel will not reorder packets. **Figure 3.8(b)** illustrates the interfaces for our data transfer protocol. The sending side of the data transfer protocol will be invoked from above by a call to `rdt_send()`. It will pass the data to be delivered to the upper layer at the receiving side. (Here `rdt` stands for *reliable data transfer* protocol and `_send` indicates that the sending side of `rdt` is being called. The first step in developing any protocol is to choose a good name!) On the receiving side, `rdt_rcv()` will be called when a packet arrives from the receiving side of the channel. When the `rdt` protocol wants to deliver data to the upper layer, it will do so by calling `deliver_data()`. In the following we use the terminology "packet" rather than transport-layer "segment." Because the theory developed in this section applies to computer networks in general and not just to the Internet transport layer, the generic term "packet" is perhaps more appropriate here.

In this section we consider only the case of **unidirectional data transfer**, that is, data transfer from the sending to the receiving side. The case of reliable **bidirectional** (that is, full-duplex) **data transfer** is conceptually no more difficult but considerably more tedious to explain. Although we consider only unidirectional data transfer, it is important to note that the sending and receiving sides of our protocol will nonetheless need to transmit packets in *both* directions, as indicated in **Figure 3.8**. We will see shortly that, in addition to exchanging packets containing the data to be transferred, the sending and receiving sides of `rdt` will also need to exchange control packets back and forth. Both the send and receive sides of `rdt` send packets to the other side by a call to `udt_send()` (where udt stands for *unreliable data transfer*).

3.4.1 Building a Reliable Data Transfer Protocol

We now step through a series of protocols, each one becoming more complex, arriving at a flawless, reliable data transfer protocol.

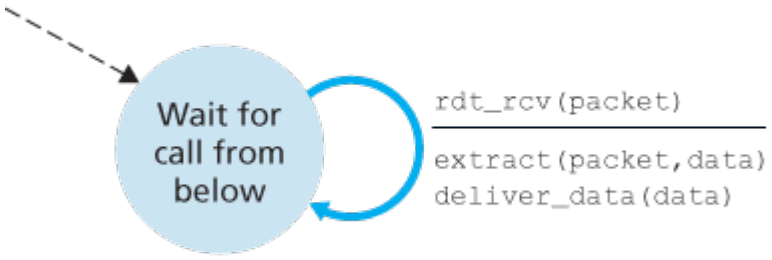
Reliable Data Transfer over a Perfectly Reliable Channel: `rdt1.0`

We first consider the simplest case, in which the underlying channel is completely reliable. The protocol itself, which we'll call `rdt1.0`, is trivial. The **finite-state machine (FSM)** definitions for the `rdt1.0` sender and receiver are shown in **Figure 3.9**. The FSM in **Figure 3.9(a)** defines the operation of the sender, while the FSM in **Figure 3.9(b)** defines the operation of the receiver. It is important to note that there are *separate* FSMs for the sender and for the receiver. The sender and receiver FSMs in **Figure 3.9** each have just one state. The arrows in the FSM description indicate the transition of the protocol from one state to another. (Since each FSM in **Figure 3.9** has just one state, a transition is necessarily from the one state back to itself; we'll see more complicated state diagrams shortly.) The event causing

the transition is shown above the horizontal line labeling the transition, and the actions taken when the event occurs are shown below the horizontal line. When no action is taken on an event, or no event occurs and an action is taken, we'll use the symbol Λ below or above the horizontal, respectively, to explicitly denote the lack of an action or event. The initial state of the FSM is indicated by the dashed arrow. Although the FSMs in **Figure 3.9** have but one state, the FSMs we will see shortly have multiple states, so it will be important to identify the initial state of each FSM.

The sending side of `rdt` simply accepts data from the upper layer via the `rdt_send(data)` event, creates a packet containing the data (via the action `make_pkt(data)`) and sends the packet into the channel. In practice, the `rdt_send(data)` event would result from a procedure call (for example, to `rdt_send()`) by the upper-layer application.

a. rdt1.0: sending side



b. rdt1.0: receiving side

Figure 3.9 `rdt1.0` – A protocol for a completely reliable channel

On the receiving side, rdt receives a packet from the underlying channel via the `rdt_rcv(packet)` event, removes the data from the packet (via the action `extract (packet, data)`) and passes the data up to the upper layer (via the action `deliver_data(data)`). In practice, the `rdt_rcv(packet)` event would result from a procedure call (for example, to `rdt_rcv()`) from the lower-layer protocol.

In this simple protocol, there is no difference between a unit of data and a packet. Also, all packet flow is from the sender to receiver; with a perfectly reliable channel there is no need for the receiver side to provide any feedback to the sender since nothing can go wrong! Note that we have also assumed that