total traffic has peaks and low points. In fact, statisticians say that data traffic is *self-similar*, which means that the traffic is analogous to a *fractal*, where the same statistics profile is evident at any granularity. Thus, if an enterprise examines a LAN, traffic from local hosts will appear bursty. If an intermediate ISP measures traffic from one thousand users or a large ISP measures traffic from ten million users, the traffic will have large absolute quantities, but will exhibit the same overall statistical pattern as the traffic on a LAN.

We can summarize:

Unlike voice telephone traffic, data traffic is bursty. Data traffic is said to be self-similar because aggregates of data traffic exhibit the same pattern of burstiness.

27.9 Passive Measurement, Small Packets, And NetFlow

Network managers who measure networks distinguish between two forms of measurement:

- Active measurement
- Passive measurement

We have discussed the disadvantage of *active* measurement techniques: by injecting traffic into a network, the measurement traffic can change the performance of the network. The alternative is *passive* measurement that monitors a network and counts packets, but does not inject additional traffic. For example, an ISP can count the bytes that are transferred over a link in a given amount of time to produce an estimate of the link utilization. That is, the ISP arranges a passive monitor station that observes a network over an interval of time and accumulates a total of the bytes in all packets.

Interestingly, an ISP may choose to measure the number of packets sent as well as the number of data bytes. To understand why, observe that because link utilization is measured as a percentage of capacity and capacity is measured in bits per second, an ISP needs to measure the total data bits sent per unit time. However, the capacity of switches and routers is measured in packets per second. The measurement arises because a router or switch performs the next-hop forwarding computation once per packet, independent of the size of the packet. Therefore, the computational effort expended to forward packets is proportional to the number of packets processed rather than the number of bits in a packet. When a stream of data arrives at 1 Gbps, a switch or router performs less work if the stream is divided into a few large packets than it does if the stream is divided into many small packets. Networking equipment vendors understand that performance depends on packets. If a particular vendor's device cannot handle many packets per second, the vendor's marketing department may focus attention on the data rate rather than the packet rate (i.e., report performance of their products when they handle large packets). The point is: