

# Packet switching

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**Packet switching** is a digital networking communications method that groups all transmitted data – regardless of content, type, or structure – into suitably-sized blocks, called *packets*. Packet switching features delivery of variable-bit-rate data streams (sequences of packets) over a shared network. When traversing network adapters, switches, routers and other network nodes, packets are buffered and queued, resulting in variable delay and throughput depending on the traffic load in the network.

Packet switching contrasts with another principal networking paradigm, circuit switching, a method which sets up a limited number of dedicated connections of constant bit rate and constant delay between nodes for exclusive use during the communication session. In case of traffic fees, for example in cellular communication, circuit switching is characterized by a fee per time unit of connection time, even when no data is transferred, while packet switching is characterized by a fee per unit of information.

Two major packet switching modes exist; connectionless packet switching, also known as datagram switching, and connection-oriented packet switching, also known as virtual circuit switching. In the first case each packet includes complete addressing or routing information. The packets are routed individually, sometimes resulting in different paths and out-of-order delivery. In the second case a connection is defined and preallocated in each involved node before any packet is transferred. The packets include a connection identifier rather than address information, and are delivered in order. See below.

Packet mode communication may be utilized with or without intermediate forwarding nodes (packet switches). In all packet mode communication, network resources are managed by statistical multiplexing or dynamic bandwidth allocation in which a communication channel is effectively divided into an arbitrary number of logical variable-bit-rate channels or data streams. Each logical stream consists of a sequence of packets, which normally are forwarded by the multiplexers and intermediate network nodes asynchronously using first-in, first-out buffering. Alternatively, the packets may be forwarded according to some scheduling discipline for fair queuing or for differentiated or guaranteed quality of service, such as pipeline forwarding or time-driven priority (TDP). Any buffering introduces varying latency and throughput in transmission. In case of a shared physical medium, the packets may be delivered according to some packet-mode multiple access scheme.

## History

The concept of switching small blocks of data was first explored by Paul Baran in the early 1960s. Independently, Donald Davies at the National Physical Laboratory in the UK had developed the same ideas (Abbate, 2000).

Leonard Kleinrock conducted early research in queueing theory which would be important in packet switching, and published a book in the related field of digital message switching (without the packets) in 1961; he also later played a leading role in building and management of the world's first packet switched network, the ARPANET.

Baran developed the concept of message block switching during his research at the RAND Corporation for the US Air Force into survivable communications networks, first presented to the Air Force in the summer of 1961 as briefing B-265 <sup>[1]</sup> then published as RAND Paper P-2626 in 1962 [2], and then including and expanding somewhat within a series of eleven papers titled On Distributed Communications in 1964 [3]. Baran's P-2626 paper described a general architecture for a large-scale, distributed, survivable communications network. The paper focuses on three key ideas: first, use of a decentralized network with multiple paths between any two points; and second, dividing complete user messages into what he called *message blocks* (later called packets); then third, delivery of these messages by store and forward switching.

Baran's study made its way to Robert Taylor and J.C.R. Licklider at the Information Processing Technology Office, both wide-area network evangelists, and it helped influence Lawrence Roberts to adopt the technology when Taylor put him in charge of development of the ARPANET.

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Baran's work was similar to the research performed independently by Donald Davies at the National Physical Laboratory, UK. In 1965, Davies developed the concept of packet-switched networks and proposed development of a UK wide network. He gave a talk on the proposal in 1966, after which a person from the Ministry of Defense told him about Baran's work. A member of Davies' team met Lawrence Roberts at the 1967 ACM Symposium on Operating System Principles, bringing the two groups together.

Interestingly, Davies had chosen some of the same parameters for his original network design as Baran, such as a packet size of 1024 bits. In 1966 Davies proposed that a network should be built at the laboratory to serve the needs of NPL and prove the feasibility of packet switching. The NPL Data Communications Network entered service in 1970. Roberts and the ARPANET team took the name "packet switching" itself from Davies's work.

The first computer network and packet switching network deployed for computer resource sharing was the Octopus Network at the Lawrence Livermore National Laboratory that began connecting four Control Data 6600 computers to several shared storage devices (including an IBM 2321 Data Cell<sup>[4]</sup> in 1968 and an IBM Photostore<sup>[5]</sup> in 1970) and to several hundred ASR-33 Teletype terminals for time sharing use starting in 1968<sup>[6]</sup>.

## Connectionless and connection-oriented packet switching

The service actually provided to the user by networks using packet switching nodes can be either connectionless (based on datagram messages), or virtual circuit switching (also known as connection oriented). Some connectionless protocols are Ethernet, IP, and UDP; connection oriented packet-switching protocols include X.25, Frame relay, Asynchronous Transfer Mode (ATM), Multiprotocol Label Switching (MPLS), and TCP.

In connection oriented networks, each packet is labeled with a connection ID rather than an address. Address information is only transferred to each node during a connection set-up phase, when the route to the destination is discovered and an entry is added to the switching table in each network node through which the connection passes. The signalling protocols used allow the application to specify its requirements and the network to specify what capacity etc is available, and acceptable values for service parameters to be negotiated. Routing a packet is very simple, as it just requires the node to look up the ID in the table. The packet header can be small, as it only needs to contain the ID and any information (such as length, timestamp, or sequence number) which is different for different packets.

In connectionless networks, each packet is labeled with a destination address, source address, and port numbers; it may also be labeled with the sequence number of the packet. This precludes the need for a dedicated path to help the packet find its way to its destination, but means that much more information is needed in the packet header, which is therefore larger, and this information needs to be looked up in power-hungry content-addressable memory. Each packet is dispatched and may go via different routes; potentially, the system has to do as much work for every packet as the connection-oriented system has to do in connection set-up, but with less information as to the application's requirements. At the destination, the original message/data is reassembled in the correct order, based on the packet sequence number. Thus a virtual connection, also known as a virtual circuit or byte stream is provided to the end-user by a transport layer protocol, although intermediate network nodes only provides a connectionless network layer service.

## Packet switching in networks

Packet switching is used to optimize the use of the channel capacity available in digital telecommunication networks such as computer networks, to minimize the transmission latency (i.e. the time it takes for data to pass across the network), and to increase robustness of communication.

The most well-known use of packet switching is the Internet and local area networks. The Internet is implemented by the Internet Protocol Suite using a variety of Link Layer technologies. For example, Ethernet and Frame Relay are common. Newer mobile phone technologies (e.g., GPRS, I-mode) also use packet switching.

X.25 is a notable use of packet switching in that, despite being based on packet switching methods, it provided virtual circuits to the user. These virtual circuits carry variable-length packets. In 1978, X.25 was used to provide the first international and commercial packet switching network, the International Packet Switched Service (IPSS). Asynchronous Transfer Mode (ATM) also is a virtual circuit technology, which uses fixed-length cell relay connection oriented packet switching.

Datagram packet switching is also called connectionless networking because no connections are established. Technologies such as Multiprotocol Label Switching (MPLS) and the resource reservation protocol (RSVP) create virtual circuits on top of datagram networks. Virtual circuits are especially useful in building robust failover mechanisms and allocating bandwidth for delay-sensitive applications.

MPLS and its predecessors, as well as ATM, have been called "fast packet" technologies. MPLS, indeed, has been called "ATM without cells" <sup>[7]</sup>. Modern routers, however, do not require these technologies to be able to forward variable-length packets at multigigabit speeds across the network.

## X.25 vs. Frame Relay packet switching

Both X.25 and Frame Relay provide connection-oriented packet switching, also known as virtual circuit switching. A major difference between X.25 and frame relay packet switching are that X.25 is a reliable protocol, based on node-to-node automatic repeat request, while Frame Relay is a non-reliable protocol, maximum packet length is 1000 bytes. Any retransmissions must be carried out by higher layer protocols. The X.25 protocol is a network layer protocol, and is part of the X.25 protocol suite, also known as the OSI protocol suite. It was widely used in relatively slow switching networks during the 1980s, for example as an alternative to circuit mode terminal switching, and for automated teller machines. Frame relay is a further development of X.25. The simplicity of Frame relay made it considerably faster and more cost effective than X.25 packet switching. Frame relay is a data link layer protocol, and does not provide logical addresses and routing. It is only used for semi-permanent connections, while X.25 connections also can be established for each communication session. Frame relay was used to interconnect LANs or LAN segments, mainly in the 1990s by large companies that had a requirement to handle heavy telecommunications traffic across wide area networks.<sup>[8]</sup> (O'Brien & Marakas, 2009, p. 250) Despite the benefits of frame relay packet switching, many international companies are staying with the X.25 standard. In the United States, X.25 packet switching was used heavily in government and financial networks that use mainframe applications. Many companies did not intend to cross over to frame relay packet switching because it is more cost effective to use X.25 on slower networks. In certain parts of the world, particularly in Asia-Pacific and South America regions, X.25 was the only technology available.<sup>[9]</sup> (Girard, 1997)

## See also

- Store and forward delay
- Time-Driven Switching - a bufferless approach to packet switching
- Public switched data network
- Packet switched network
- Optical burst switching

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## Further reading

- Katie Hafner, *Where Wizards Stay Up Late* (Simon and Schuster, 1996) pp 52–67
- Janet Abbate, *Inventing the Internet* (MIT Press, 2000) ISBN 0-262-51115-0
- Arthur Norberg, Judy E. O'Neill, *Transforming Computer Technology: Information Processing for the Pentagon, 1962-1982* (Johns Hopkins University, 1996)

## External links

- Oral history interview with Paul Baran (<http://www.cbi.umn.edu/oh/display.phtml?id=110>). Charles Babbage Institute University of Minnesota, Minneapolis. Baran describes his working environment at RAND, as well as his initial interest in survivable communications, and the evolution, writing and distribution of his eleven-volume work, "On Distributed Communications." Baran discusses his interaction with the group at ARPA who were responsible for the later development of the ARPANET.
- Packet Switching History and Design ([http://www.livinginternet.com/i/iw\\_packet.htm](http://www.livinginternet.com/i/iw_packet.htm)), site reviewed by Baran, Roberts, and Kleinrock
- Paul Baran and the Origins of the Internet (<http://www.rand.org/about/history/baran.html>)
- A Brief History of the Internet (<http://www.isoc.org/internet/history/brief.shtml>)

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