In person

Packet-switching's unsung hero

The most significant development in telecommunications since Arthur C. Clarke first thought of using geostationary satellites has been the packet-switched network. Rex Malik talked to its largely forgotten inventor, Paul Baran, while in the United States recently

In the world of advanced applied technology, particularly in the field of computing and telecommunications, an innovator aiming at the heights must be prepared to accept the hassle of public relations. He must be ready and willing to expend a percentage of his lifetime, however small, in emotional energy, wit, time, and cash to ensure that he receives his just rewards. Otherwise, although among his peers he may be a mountain, to the outside world he will be simply a molehill. If he is not temperamentally attuned to such a life, then with luck, after his death, the world rediscovers him. Writers start to dig into history and a fine old row develops about who did what and who should get the credit.

All that is by way of introduction to perhaps the hottest property in telecommunications (next to satellites) of the past 20 or 30 years. It is called packet-switching, and is an attempt to transfer some basic digital computing notions to the field of telecommunications. Put at its simplest, packet-switching uses the digital coding concept to transform a message from words into packets, each carrying its own coded address and transmission instructions, on which the network acts (see box).

You would think, then, that the origins of packet-switching would be quite clear; and that the originator, now just turning 50, would be, if not honoured, at least not unsung. You would be wrong.

Bill Sanderson

The name is Paul Baran. He is unassuming, quiet, reflective, and almost dapper. He is now president of Cable Data Inc, a little company tucked away in Palo Alto, California, in the heart of "Silicon Gulch". It is a company about which he says little, except that its title is almost totally misleading—which is also a pretty apt description of the development of packet-switching. Rand Corporation, for instance, published his 13-volume study, in which packet-switching was first described, and disarmingly called it *On Distributed Communications*.

The study was first published in 1964, but only eight volumes are in the public domain; the rest are still security barred. For, as so often happens with advances in computing and communications, the advance is inextricably intertwined with the needs of defence. The military strategy of the time was aimed at giving the United States a second-strike capability. But the weakness of the strategy lay in its weakest link, communications.

The initial requirement which Baran faced was to work out how to create a communications system which could survive a nuclear first strike—so that whatever parts were damaged there would still be a transcontinental route available, and thus there would be the ability to initiate a second strike. "The question," says Baran, "became how do you build a very reliable structure out of very unreliable components?

"I didn't set out to build packet-switching systems as such. The first of the systems I looked at was just using existing broadcast stations to relay messages from one another. I could show that a fairly good survival structure could be built. But the generals came back saying, 'Well, that's OK for this purpose, but we have to do this and that.' When I added up all the requirements for communications after an attack, it was so long that I said: 'To hell with it; let me sit down and see if I can't come up with a communication network that has such wide bandwidth that it could handle all requirements'."

What did Baran achieve? Well, he solved the problem by what now seems a simple trick: he changed the nature of the communications system, though much of the technology the system would adopt was exactly the same as it was then using. "If you can get by with unreliable components, you reduce the cost tremendously," says Baran. "Most of the cost in a communications system is spent in making reliable elements, because most communications systems assume that every element between the two people who wish to communicate are operative at any one time. But if you build a communications network in a fashion where only a subset of the elements have to work at any one time, then you end up with an infinitely more reliable structure."

It is not only here that Baran was radical. Take his approach to the bandwidth problem. In a traditional system, what determines the bandwidth required is the nature of the signals to be sent, and the speed at which they need to be transmitted. Thus speech, which is really rather slow in data terms, requires quite narrow bandwidth. Conversely, to send a television signal, which carries a lot of information, one needs high speed and a relatively wide bandwidth. However, if instead of sending an analog waveform of the information to be conveyed, you transform it into binary-coded data (which can be decoded and re-assembled into proper information at the reception end) then it becomes very nearly independent of speed and bandwidth.

Baran was faced with a situation in which the bandwidth requirements were large, because of the great variety of types of data the system would have to be carrying. And he was faced with a maximum security requirement. He solved the problem by proposing a system with a very wide bandwidth, beginning at 1·5 megabits per second to go eventually to 15 megabits per second. The speed, however, was not linked to the nature of the data but to the security requirements. He envisaged transmission in terms of very short, high speed bursts. The best we have done so far is 56 kilobits per second, which is a measure of how advanced his proposals were. In effect, Baran invented a self-loading network.

The key is that the network's capacity is not restricted by the loading on any one channel, but by the loading on all channels. Because of the cover connection (if viewed in serial terms) it is possible to spread the communications across the network. What determines the acceptability of the system to the user now becomes the time delay, and serious time delays do not occur until the entire communications network is loaded. This has implications for investment decisions.

"How do you build a very reliable structure out of very unreliable components?"

How did Baran get into this in the first place? It began in theory after a BSc in electrical engineering from Drexel University in 1949 where he specialised in communications, followed 10 years later by an MSc in computing from UCLA. In practice, it was the other way round. Almost his first job, in the late 1940s, was with the Eckert Mauchly Computer Company which created Univac One. He left, as he says, because Eckert and Mauchly were inventing aspects of computing as they went along. Baran felt there was not going to be much future there. But he was to be irresistibly drawn back to it, because every communications system he was involved with thereafter seemed to have some sort of digital box connected to it.

He went to Rand Corporation in the late 1950s and was to spend the best part of 10 years of his life there—and not just working on packet-switching. He is, in fact, better known in the United States for his deep involvement in the problems of privacy and security which computing brought with it.

After Rand, Baran helped found the Institute for the Future with Olaf Helmer, widely known as the creator of the Delphi forecasting technique. And it was here that he became even better known within the computing community as an early proponent of the computer in the home. It is something on which he still works today but he will not talk about it. Baran moved on to become involved in massive studies into the future of telecommunications, the development of devices of many kinds, and the creation of a remote conferencing system.

I asked a senior telecommunications engineer whether he had ever read those eight volumes and, if so, what did he think of them. "Ah," he said, "good conceptual ideas in this business are few and far between. Most of what we do consists of upgrading old techniques with faster and more complex technology. Baran's work was the most original and exciting concept since Arthur C. Clarke thought it might be possible to have a telecommunications satellite system." □

Value of over-connection

Packet-switching demands a different kind of communications network from the normal telecommunications pattern. The channels, whether wire or radio, may be the same; but the switching points and exchanges have "intelligence"—some form of computing device—which can accept a packet, look at it, and send it on its way according to the address and instructions it carries.

There is, however, also another major difference. The traditional communications network is essentially serial. To make a connection between two subscribers to such a system requires that the connection be established for the duration of the call. This means that the right switches have to be opened/closed and kept so for that duration.

Such a requirement is not necessary with a packet-switched system or network. In this latter case, you transmit your data to the network, which then takes over, either sending it on or holding it until the addressee's receiver facilities are free and able to take it. The speed of transmission thus becomes a function of the weight of loading within the network. At the conceptual level, this is quite a radical approach to telecommunications.

To have a fail-safe network, in the terms that Baran proposed, there should be "over connection". In other words, there should be not just one path in or out for a packet, but several. What would then determine the routing is the availability of a channel at a particular time. With this sort of network, the reliability can be far lower than would be necessary for a "normal" linear communications system.

People have been trying to build such networks now for around 10 years. Today, though no one can be certain how many are being planned or built, most of the communications networks of which we have high expectations are packet-switched—among them the experimental Arpanet in the United States, the commercial Telenet network (also American), Europe's interbank Swift network, Euronet, and the European Informatics Network. □