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### 2021-08-03 key systems

programming note update: the ongoing reliability problems with computer.rip have been tracked down to a piece of hardware which is Not My Problem, and so I anxiously await the DC installing a replacement. Hopefully the problem will be resolved shortly.

And now for more about telephones, because I am on vacation in Guadalajara and telephones are decidedly a recreational topic. If you follow me on twitter I am probably about to provide an over-length thread on some Mexican telephone trivia.

Back when I was talking about turrets, I mentioned their relationship to *key systems*. While largely forgotten today, key systems were an important step in the evolution of business telephone systems and remain influential on business telephony today. Let's talk a bit about key systems, including some particularly notable ones.

But first, it would be helpful to understand the landscape of business telephony systems. I'm writing this from the perspective of today, but I think this overview will be helpful in understanding the context in which the key system was invented and became popular.

Most businesses have a simple problem: they have, say, ten employees, each with a phone, but they do not want to pay the considerable expense of having ten telephone lines in service. It would be much better to have, say, two telephone lines, which were shared among the employees. The first and most obvious solution was the *private branch exchange*, often abbreviated PBX. In a classic PBX arrangement, one or more outside lines terminate at a small manual exchange (the type with operators that insert plugs to connect lines). The PBX can provide the same services as a telco exchange, including answering incoming calls and directing them to inside lines, but comes at the significant disadvantage of requiring an operator.

Today, it's not unusual for a front-desk receptionist or other similar employee to serve as the de facto telephone operator (usually today called an "attendant" to differentiate from the older position of a dedicated operator), answering incoming calls and directing them appropriately. The design of a manual telephone exchange made this impractical, though, as even small manual exchanges were pretty large and nearly required wearing a headset... wearing a headset and sitting behind a plugboard was not amenable to greeting guests or other typical receptionist tasks, so a dedicated, full-time telephone operator was basically required. This made PBXs very expensive to operate, in addition to the considerable expense of purchasing one.

The solution here seems obvious: the Private Automated Branch Exchange, or PABX. A PABX uses automatic switching rather than manual. Outbound calls can be made by dialing, while inbound calls can be managed by various techniques like DID or an

automated attendant. In the case of DID, Direct Inward Dialing, the telephone company assigns a unique telephone number to each employee of a company even though the company does not have that many lines (for practical reasons related to how mechanical switches hunted for available lines, in early cases these numbers usually had to be sequential). When the telco connected a call to the PABX, it used some technique to indicate the number the call had been dialed to originally--early on this was often the delightfully named Revertive Pulsing, where once the PABX "answered" the line the exchange pulse-dialed *back* to the PABX, often with the last n digits of the called number.

In the case of an automated attendant (AA), the PABX answers and plays an audio recording prompting the caller to enter an extension. It then connects the call appropriately. The AA may optionally provide a menu of usually single-digit options, although this is a bit more complicated to implement and was not as common on early PABXs.

DID and AA are both ubiquitous today. The use of telephone extensions inside of businesses has generally decreased over the years as DID has become easier and cheaper to implement, but AAs remain common for telephone menus, which may straddle the line between a "mere" AA and the more complicated interactive voice response (IVR) system.

Here's the problem, though: in the early days of business telephony, DID and AAs were both very complex to implement. Early PABXs were mechanical, even Strowger (also called step-by-step or SXS), and the introduction of DID significantly complicated the switching matrix. The lack of good, reliable audio playback devices and the lack of universal DTMF signaling made AAs impractical for quite some time.

So, here is the problem: for smaller organizations, which could not justify the expense of employing a telephone operator during business hours, there were few practical options. PABXs were too expensive and too limited, often still requiring a full-time operator to handle incoming calls [1].

The key system was introduced as a compromise. Like a PABX, it does not require an operator. But, a key system is substantially less complex and expensive than a PABX. What's the trick? A key system makes *everyone* act as the operator.

When I previously mentioned key systems I put it like this: a PABX connects many users to each line. A key system connects many lines to each user.

Lets say again you are a small organization with about ten employees and you want to pay for two lines. When you install a key system, you connect the two outside lines to a Key Service Unit (KSU). The KSU is then connected to each of the ten telephones by a large, multi-pair cable, often a 25-pair Amphenol type connector. Superficially, it may look like a PABX, but the use of the multi-pair cable is a big hint to what's going on: the KSU only provides very minimal electrical conversions and mostly just acts as a jumper matrix. All of the actual logic is in the telephones, each of which have all of the outside lines connected directly to them.

The "key" in "key system" refers to the "line keys" on each phone. In our notional two-line system, each phone has two buttons labeled "line 1" and "line 2." Whenever a line is in use, the button lights. When a line is ringing, the light flashes and the phone may ring depending on configuration (ringing can usually be enabled/disabled per line to provide a simple concept of "call groups" if the outside lines have different numbers).

To place a call, a user presses a line key that is not lit, which connects their phone directly to that outside line. They then dial normally. To answer a call, the user presses the flashing line key and then picks up the phone. All they really have is a phone that is connected to all of the outside lines, the key system just makes it possible to have many phones connected this way at once.

Of course, early on key systems sprouted additional features. Even the earliest key systems started to offer an “intercom” feature, in which one or more pairs on each phone were connected to an “intercom bridge” in the KSU. This provided a feature that is superficially like a PABX’s inside calling: a user can press an intercom key and then dial a number, which causes another phone on the system to ring. When that person answers, they can have a conversation. Of course the simple design of the feature imposes a lot of limitations, and generally only one intercom call can be made for each assigned intercom bridge on the system. This was often only one or two.

You can also see that key systems pose a significant risk of “collisions.” Later key systems often included a “privacy” feature that locked out phones from connecting to a line when it was currently in use, so that other users could not eavesdrop on your calls. The feature could similarly prevent someone trying to make an intercom call suddenly being placed in an existing call. Of course these features meant that if all outside lines or all intercom bridges were in use, it was simply not possible to make a call. The line key lights served an important purpose in showing users when a line was available for their use.

Perhaps the quintessential key system is the Western Electric 1A and descendants, which were in widespread use for decades around the mid century. Later revisions of the 1A such as the 1A2 supported as many as 29 lines to each phone (this required multiple 25-pair cables per phone!) and advanced (for the time) features such as attended transfer and music on hold.

Key systems were often designed flexibly to reduce cost of installation. For example, outside lines might be allocated to different departments. Most phones would only need to be connected to the lines for their department, but a receptionist might have a “call director” phone that presented all lines so that they could answer calls for multiple departments [2].

My favorite key system, though, is the AT&T Merlin. The Merlin was a late digital key system, introduced in 1983, and so began to blur the line between key system and PABX. Most importantly, though, the Merlin telephone instruments were beautiful. Seriously, look at them. An advertising campaign including product placement in films and television reinforced the aesthetic cache of the Merlin. The campaign is said to have been so successful that the Merlin instruments became something of a status symbol, and client-contact organizations like law firms would upgrade from 1A2 to Merlin just for the desk decorations. I recall having read once that the Merlin was a key inspiration for the design of the NeXT Cube under Steve Jobs, but I cannot find a source on this now so perhaps I just made it up. I certainly hope it’s true!

It might seem that key systems would be an artifact of history today, entirely outmoded by the availability of inexpensive PABX systems. There were a lot of disadvantages to key systems. Besides the issue of users having to manually select lines, and limited logic on ring groups, the large multi-pair cables required to telephone instruments made key systems expensive to install and not amenable to reuse of existing phone cabling in a building.

The funny thing is that sort of the opposite happened. The low-cost PABXs that became

readily available in the 1990s were actually more descended from key systems than the earlier electromechanical PABXs. The small business PABX I have in my house, for example, the Comdial DX80, is basically an overgrown key system. Yet it has many of the advantages of an earlier PABX!

Here's the trick: the availability of computer-controlled digital switching and communications allowed for implementing a "key system" using a standard two-pair line to each telephone. Small businesses were usually upgrading from key systems and expected similar behavior. So it just made sense to take a suite of PABX features and shove them into a key system, using digital signaling to simplify the installation of the system.

So the DX80 for example works like this: the KSU communicates with the phones using a digital protocol over a single-pair telephone line. Each telephone instrument can be equipped with a full set of line keys for the KSU's up-to-16 outside lines, but the KSU is also capable of automatically selecting outside lines and automated incoming call routing based on DID or an auto-attendant. Internal calling between phones is managed digitally and is not limited to one or two intercom lines. All this adds up to flexibility: you can use the DX80 as *either* a key system or a PABX, depending on how you configure it. You can leave automated line selection un-configured and present line keys on the phones, or you can remove the line keys from phones (reallocating them to other uses) and set up fully automatic call handling.

Many organizations ended up doing both!

A lot of '90s to '00s PABXs were like this. They had sort of an identity crisis between key system and PABX where they wanted to present the convenience of a PABX without removing the familiar line keys for direct access to outside lines. Those line keys could be important, after all, as not all businesses had a DID arrangement (or even disconnect supervision) from their telco, so the use of the line keys allowed for connecting the PABX directly to a "normal" telephone line without needing to get the telco to enable additional features.

Today, most business telephone systems are being converted to VoIP which can provide additionally flexibility and features, and basically obsoletes the concept of a key system since the "number of lines" on a VoIP trunk is a largely synthetic concept. Nonetheless, most VoIP systems can be configured for key-system-like behavior if you really want it.

[1] I have omitted from this discussion the Centrex and other forms of telco-operated PABXs. I will probably do a full post on these in the future. For a short time I worked for a large organization which owned a formerly AT&T-operated 5ESS as their PABX and had the pleasure of getting an extensive tour of the system from one of its few remaining on-site technicians. It has since been decommissioned. As a basic hint, when an organization is large enough to have one or more exchange codes to itself (often seen with universities and older large corporations), it's likely that they had an on-site PABX provided by the telco. If an organization had a set of sequential numbers but no on-site switch, they probably used Centrex, which was basically the same arrangement except for the switch was located in a telco office (and often "virtualized" on an existing ESS). Centrex was also popular with organizations that were very large but had multiple facilities, like school districts, since the existing telco exchange office was as convenient of a central location as anywhere else. That said, the nature of their close relationship to government meant that school districts often found it convenient to run their own private trunk lines between buildings, and so they may have still used an on-site switch.

[2] The term “call director” is still sometimes used today to refer to phones with an unusually large number of line buttons, often on a device like a “receptionist sidecar”. The terminology is confused by “Call Director” also being the name of various PABX products and features.