The step-by-step telephone switching system: handling of toll calls

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FOREWORD

In the 1920s and 1930s, the US had a well-developed, and very complex, system for handling long distance ("toll") telephone calls, much of it operated by The Bell Telephone System.

Step by step (SXS) switching equipment played two major roles in that scheme. Even during the era in which connections through the "interior" of the toll network were set up with manual cord switchboards, the completion of a toll connection to a subscriber served by an SXS system was done through a special part of that system, using special versions of the SXS switches.

Then as the system evolved, special types of SXS switching equipment were used in the interior of the toll network, allowing the toll operator who initially handled the call to, by dialing, set up the entire toll connection all the way to the called station.

These SXS switching arrangements use control and signaling arrangements quite different from those of the SXS equipment used for local calls. These in part arose to support special modes of call handling often involved in the long distance service.

In this article we get an insight into how these SXS switching arrangements worked. It begins with extensive background on the surrounding context. The basic overall architecture of a toll call, as of the period of interest, is shown. Then the switch trains involved are described in detail from a functional viewpoint. The signaling and control protocols for the trains are described in detail in an appendix.

1 GENERAL

1.1 Caveat

This entire area is extremely complicated, and comprehensive, and authentic documentation is hard to come by. The author has relied on a wealth of information, including patents from the era of interest, but not every explanation "reaches from cover to cover". Accordingly, in my detailed descriptions there will be some loose ends.

1.2 Reader background

It is assumed that the reader is generally familiar with the operation of the step-by-step (SXS) telephone switching system. If more information is needed, I commend the reader to the lead article of this series, "The step-by-step telephone switching system–Overview".

1.3 The hardware

The SXS switches described in this article use basically the same mechanisms, and operate in generally the same ways, as the switches used in "local" SXS switching systems, although there are some very significant operational differences, the most important of which will be described at length in this article.

1.4 The term "toll"

Long distance calls early became described as "toll" calls in recognition of the fact that they were normally charged for "by the each", the charge (a "toll") generally depending on the duration of the call and the distance between the two stations. This was as distinguished from local calls, which generally were either "free" (that is, an unlimited number were included in the monthly change for the service) or charged for as a small fixed amount each after some "free" monthly ration has been used.

Then, the modifier "toll" became used in the names of almost everything involved in long distance service (toll switchboards, toll operators, toll central offices, toll cables, toll switching machines, toll transmission plans, etc.).

2 TECHNICAL BACKGROUND

2.1 The step by step local switching system

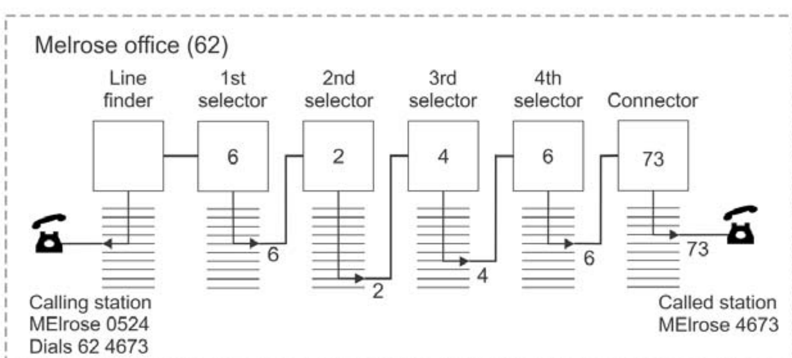

Figure 1. Local intraoffice step by step connection

For reference and comparison, Figure 1 shows in simplified block diagram form an **intraoffice** local connection between two telephone stations served by the same step by step (SXS) switching system central office.

The example presumes six-digit telephone numbers, with the first two digits indicating the serving central office (which in this example is the same central office that serves the calling station).

Then, to complete the picture, Figure 2 shows in the same way an **interoffice** local connection between two telephone stations served by SXS switching systems in different central offices, with that same numbering plan.

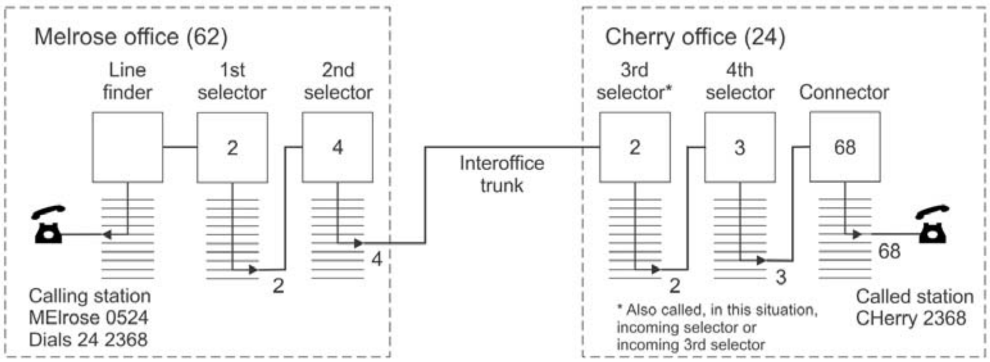

Figure 2. Local interoffice step by step connection

3 DELIVERY OF A TOLL CALL—THE TOLL TRAIN

3.1 General

If we consider, for example, the early 1930s, switching in the interior of the toll network was, with a very few exceptions, done on a totally manual basis, with special cord switchboards. Consider that context for now.

Suppose now that the called subscriber in a toll call is served by an SXS office. Then the call is "delivered" from the last manual toll switchboard in the interior of the connection to the called line by a special train of SXS switches. Although this train, the "toll train" [1], directly parallels a corresponding part of the local switch train, there are many important differences in its operation (which is in fact one point of this article).

In Figure 3 we see one example of a toll connection, manually switched in the toll network proper, delivered to a called station served by an SXS local office.

[1] It is sometimes more-descriptively called the *toll completing train* and I will generally use that term here for greatest clarity. It is often sometimes called the toll switching train

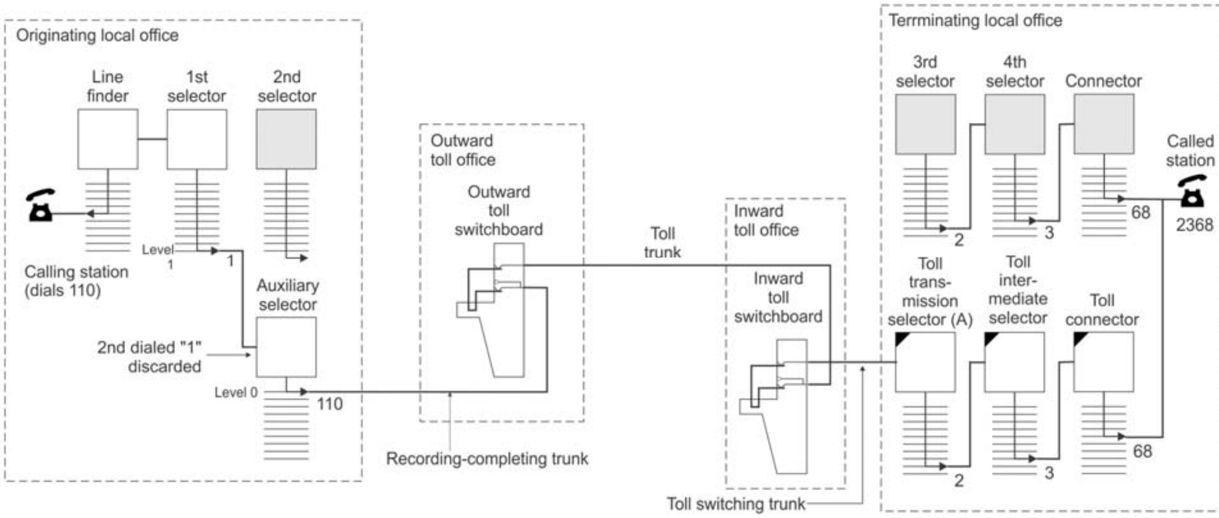

Figure 3. Completion of a manual toll call

In this example, the connection in the toll network proper is a simple one, involving only two manual toll switchboards, known as the *outward* and *inward* toll switchboards, with a direct *toll trunk* between them. (Of course in many real cases, some intermediate switching may be involved, but we do not need to think about that here.)

The operator at the outward toll switchboard is responsible for the call, and will administer it from beginning to end. The operator at the inward toll switchboard is responsible for extending the connection to the toll train at the destination office, but she then stands back until the call is finished and the outward toll operator releases the connection.

In the example, the calling station is also served by an SXS office. As was often the case in this situation, the caller dials 110 to reach the "long distance operator". The first dialed 1 takes the *1st selector* to level 1, where it reaches an *auxiliary selector*. Several other services reached by this selector also have three-digit codes beginning with "11" (*e.g.*, "information"[2], 113).

The strategy for handling that scheme is that the auxiliary selector would "discard" a dialed (second) digit of "1".[3] Then, in this example,

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[2] Known in modern times as "directory assistance", to avoid any possibility that customers would think that they could call this number to ask about the population of Argentina.

[3] This was actually called "digit absorption". This strategy was used to save switch stages.

the third digit, “0”, takes the auxiliary selector to level 3, where it accesses a trunk to an outward toll switchboard.[4]

The caller passes the wanted city and telephone number to the outward toll operator. From her “Rate and Route Guide”, she finds what group of trunks she should use to extend the connection to that city. In this example, I assume that there are direct trunks to the destination city–that is, to the inward toll switchboard there.[5]

The outward operator selects an idle trunk in that group and plugs into it with her “calling” (front) cord. Through signaling that is beyond the scope of this article, this alerts the operator at the destination inward toll switchboard.

The outward operator passes the called number to the distant inward operator. The inward operator plugs into a *toll switching trunk*[6] to the office (SXS in this example) serving that number. The inward operator dials (perhaps four digits) into the *toll train* at that office. There, two selectors (of two different special types) and a connector (of a special type) establish a connection to the called line.

I have marked the switches of the toll completing train, which are quite different in the details of their operation from the corresponding switches in the local train, with a little black triangle in the upper left corner.

I will discuss those differences at length later.

Note that the trunk labeled “toll trunk” could be appropriately called an *intertoll trunk*, since it runs **between** toll offices. But that term did not prominently appear during the era of the architecture shown. Keep it in mind, though.

3.2 Intertoll dialing

Beginning in perhaps the mid 1930s, switching in the toll network proper began to be “mechanized”. The type of switching equipment that could be most expediently adapted to this was SXS equipment.

Figure 4 shows the result of a connection made in this way, again for the simplest connection in the interior of the toll network.

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[4] This is called a “recording-completing” trunk for historical reasons that are beyond the current scope of this article.

[5] That inward toll switchboard may in fact serve many cities in the same area. It will have “toll switching trunks” to each of them.

[6] The name presumably refers to the fact that the trunk leads to a “switching system”.

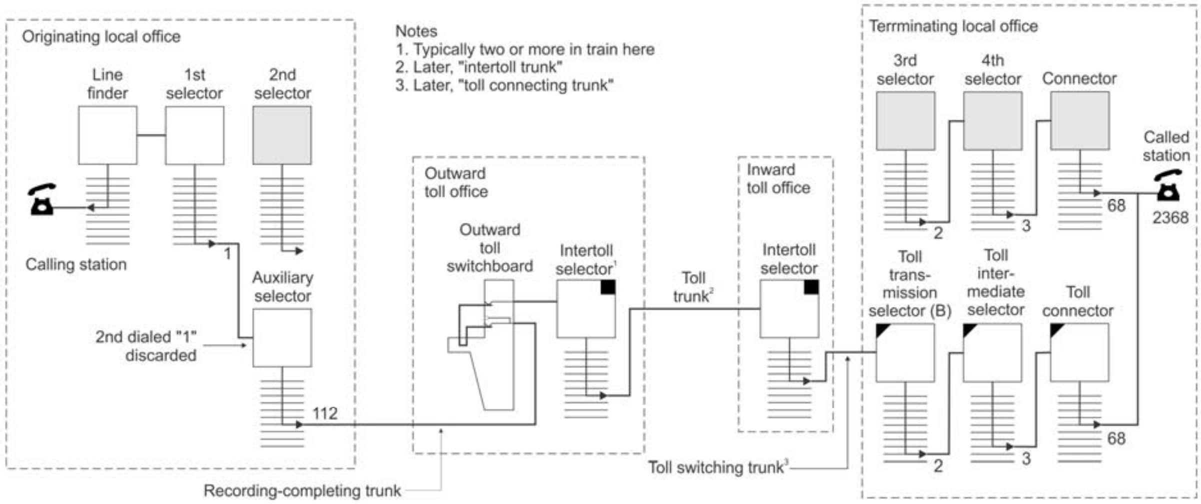

Figure 4. Intertoll dialing

For the most part, the toll train now operates in the same way as was described above.

Here, the outward operator dials a series of arbitrary digits to establish a connection, through SXS switches (*intertoll selectors*), to the toll train at the destination office. The example assumes that there was a direct trunk to the destination toll office. But if no such was available, the operator might have dialed through an intermediate toll office, again using arbitrary digit sequences.

This scheme of setting up the "interior" part of the toll connection (that is, between toll offices) by dialing into switches was known as "intertoll dialing". The switching train used was called the "intertoll train". Later, the trunks between toll offices came to be called "intertoll trunks" (and I will use that term here).

The signaling and control protocols used in the *intertoll trai*n were quite different from those used in the *toll completing trains* at the destination local offices. The *toll transmission selector*, the "incoming selector" of the toll train (but in a sense the end of the *intertoll train*), among other things mediated between the two sets of protocols.

Just as I had marked the switches that were part of the *toll trains* with a little triangle, I have marked the switches that were part of the *intertoll train* with little black squares in their upper right corners.

I call attention that the toll transmission selector seen here (labeled "B"—my notation only) is different than that seen in Figure 3 (labeled "A"). The "front end" of the "A" kind is arranged for an intimate relationship with a toll switchboard. The front end of the "B" kind is arranged for more generalized access by way of an intertoll trunk.

4 TALKING BATTERY FOR TOLL CALLS

4.1 Introduction

An important consideration in the architecture by which toll calls are completed with SXS equipment is the matter of “battery feed”. In this section, I will the give some background on that matter.

4.2 About “battery”

In the field of telephone systems, the DC voltage that is used for many purposes (energizing telephone lines, operating relays in switching equipment, etc.) is referred to as “battery”. This flows naturally from the fact that traditionally that this voltage (typically nominally 24 V in manual switching systems, 48 V in “machine switching” systems) is provided by a storage battery “floated” across the output of a DC power supply.

4.3 The carbon transmitter

From the introduction of the *common battery* mode of operating telephone lines through perhaps the 1980s, almost all telephone sets used a transmitter (microphone) of the *variable-resistance carbon* type. Here, the diaphragm, responding to the acoustic speech wave, flexes a conductive wall of a small chamber filled with carbon granules. The opposite wall is also conductive. As the pressure through the mass or carbon granules changes, the resistance through the mass (between the two conductive walls) varies.

A nominally-constant DC current is passed through the transmitter. As its resistance changes so does the voltage across it, following the acoustic wave. The varying component of that voltage is an AC “audio”[7] signal reflecting the speech.

For a given acoustic input, the level of the electrical output signal varies significantly with the level of the DC current.

4.4 Battery feed

In all but some specialized cases, under the *common battery* principle, the DC current that energizes the transmitter the DC current that flows in the telephone line, supplied from the serving central office. Given its importance to the operation of the transmitter, it is often spoken of as *talking battery*.

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[7] But we never say “audio” in this context, Rather, such signals are called “speech” or “voice frequency” signals.

In many cases, the circuit that feeds the DC current is closely integrated with the circuit that couples the speech signals between the two sides of the switch (or other circuit).

In Figure 5, we see where the battery is applied in our example **intraoffice** local connection with SXS equipment once the connection is completed.

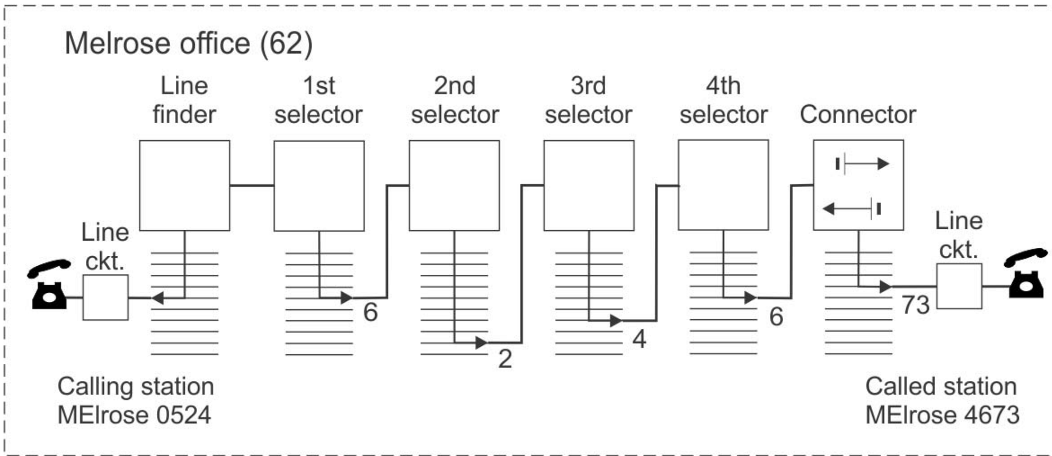

Figure 5. Local intraoffice step by step connection–battery feed

We see that the connector feeds the battery to both stations.

In Figure 6, we see where the battery is applied in our example **interoffice** local connection with SXS equipment, again after the connection is completed.

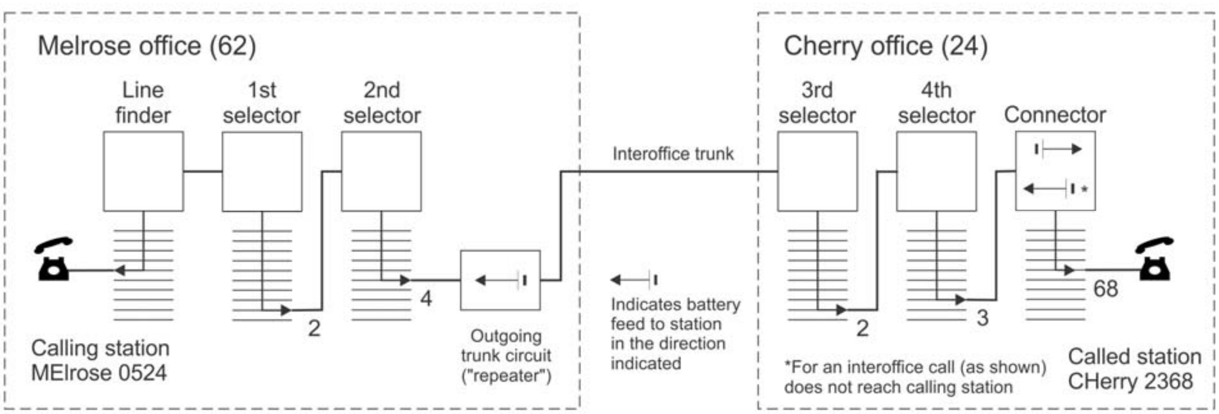

Figure 6. Local interoffice step by step connection–battery feed

We note that, as in the intraoffice case, the connector provides talking battery both "forward" (to the called station) and "backward", but here the latter does not reach the calling station. Rather, in this case, the talking battery is feed to the calling station from the trunk circuit[8] at the near end of the interoffice trunk.

The reason it is done this way is that the combined resistance of the interoffice trunk and the calling station line might reduce the current below a desirable level were it in fact provided from the connector.

Keep this structure in mind for later when I will discus departures from it in the operation of the toll network.

4.5 Loss in a toll connection

"In the day". trunks in the interior of the toll network were conveyed over physical pairs (either on open-wire lines or in "toll cables"). Eventually, repeaters (amplifiers) were used to overcome, in part, the attenuation that would be afforded by those lengthy pairs.

But for reasons that are beyond the scope of this article, there was a lower limit on the loss of these "repeatered" pair circuits, based in part on their physical length. The result was that for a "long" toll connection, the loss of the interior portion might be quite substantial.

4.6 One mitigating factor

One way to overcome this was to strive for the greatest possible electrical signal output from a telephone set for a given level of speech.

One factor that directly influences the electrical output from a telephone set for a given speech volume is the DC current through the transmitter, which is in fact the DC current in the line. (See section 4.3.) Thus in a toll connection, it was sought to make that current consistently at the greatest value that was practical. This had a substantial influence on the siting and design of the transmission circuits that formed part of the toll completing trains.

4.7 Battery feed circuits

4.7.1 *In a local connection*

For reference and comparison, Figure 7 shows a typical example of the transmission circuit used in an interoffice local call in the SXS system, one of whose jobs is to provide talking battery feed to the two lines.. As we saw earlier, this occurs in the connector.

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[8] Actually called a "repeater", since one of its purposes is to repeat the dial pulses over the interoffice trunk.

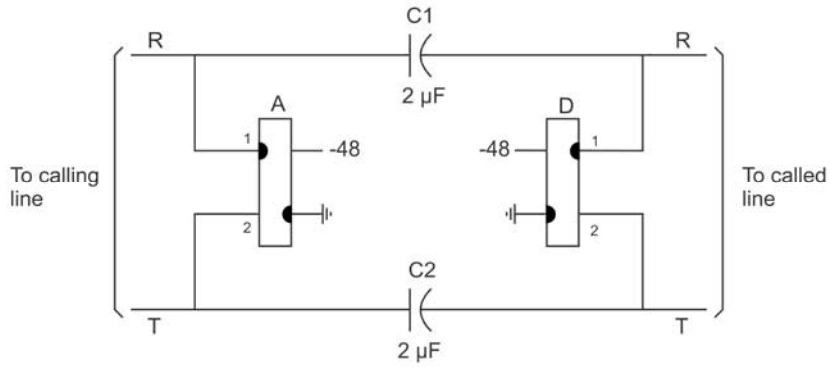

Figure 7. Illustrative local transmission circuit

Battery and ground (collectively, "battery") are fed to each line through balanced windings of two relays (here labeled with their typical designations in a local SXS connector). The real purpose of these relays is to determine whether the two lines are on hook or off hook. Thus they are actually *supervisory relays*, but because of one major purpose of this circuit, they are most often described as "battery feed" relays.

The speech signals are carried between the two lines through coupling capacitors C1 and C2.

The relay windings have fairly large inductances. Thus they do not "short circuit" the AC speech signals.

This circuit does not regulate the line current, which varies with line resistance. Thus for a longer line, with a greater resistance, the current is less, and thus the transmitter output is less. But because of the increased loss of a longer station line, this is just the time we would rather not have a lower transmitter output. Still, in local service, even subscribers on longer lines received "acceptable" end-to-end transmission performance.

I note also that in manual switching systems, the battery voltage normally used was 24 V, which made the situation here even "worse".

4.7.2 *On toll connections*

But especially in the earlier days of long distance service, where it was difficult to fully overcome the attenuation of the various lines, this shortcoming of the basic SXS battery feed circuits would be particularly adverse.

This suggested that when the telephone set was involved in a long distance connection, it was desirable to use a different transmission circuit, one with a less-primitive battery feed circuit. Figure 8 shows a typical "toll" transmission circuit:

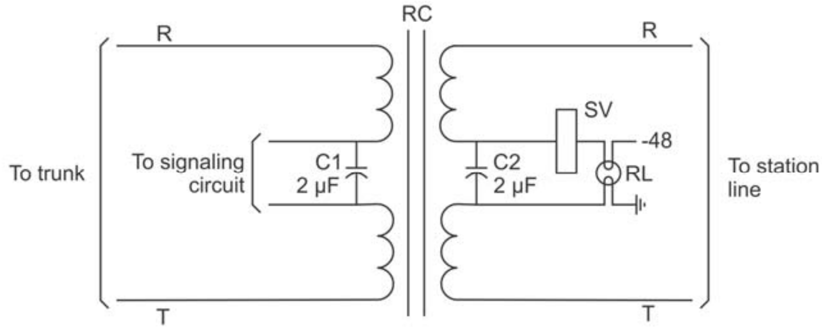

Figure 8. Illustrative toll transmission circuit

Here, the line current is regulated by resistance lamp RL. As the current through it increases, the filaments get hotter, and their resistance increases. Thus the current through the lamp remains relatively constant with changes in the resistance of the "load" (in this case, the station sets as seen though their lines). This is spoken of as "toll grade battery".

The coupling of speech circuits across this circuit is done through a *repeat coil* [9] (audio transformer), RC.

Relay SV ("supervisory") has a fairly low resistance. Its purpose is to determine whether there is current flow in the circuit or not, and thus determine whether the station is on hook or off hook.

Capacitor C2 provides a low impedance path for speech signals, preventing any significant fraction of the speech signal current from passing through SV and RL, where the power it represented would be dissipated and thus lost. A similar situation is seen at he "left side" of the repeat coil, where the two conductors handle DC signals that are part of the trunk signaling protocol.

A secondary benefit of this circuit is that the transmission loss through it is typically a bit less than through the "local" transmission circuit see just earlier.

The need to utilize this circuit leads to a couple of the differences between they way SXS equipment is configured and operated in local and toll connections.

4.8 Siting of the battery feed

Figure 9. shows the same toll connection shown in Figure 4 except that the siting of the battery feed to the two stations is now indicated.

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[9] At first called "repeating coil", since its job was to "repeat" the speech signal.

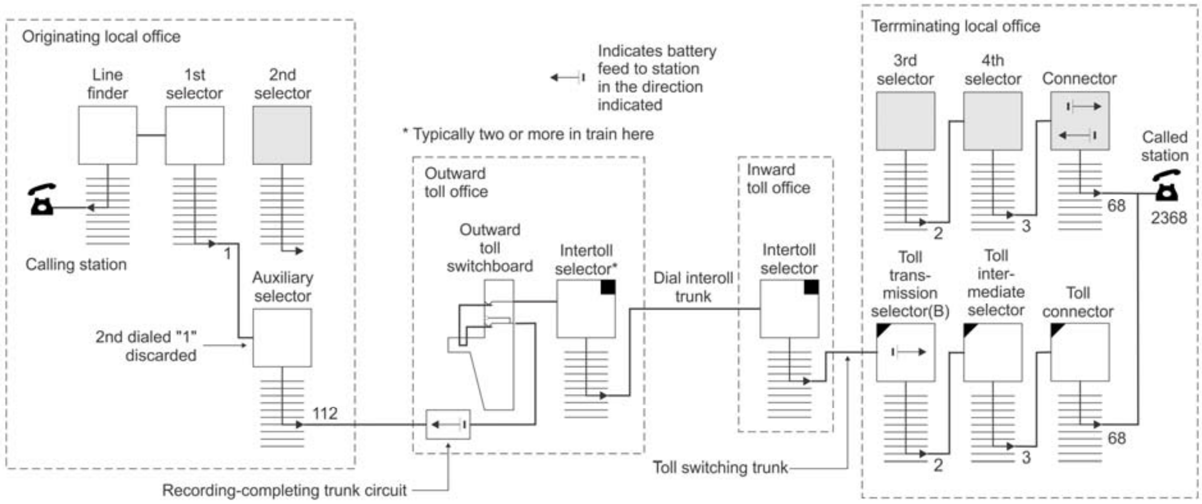

Figure 9. Toll connection showing battery feed to stations

Firstly, for comparison, at the top of the terminating local office we see a reminder of where battery feed is sited in an intraoffice local connection.

In the toll connection, we see that battery is fed to the called station from the *toll transmission selector*. And of course there is a transmission coupling path there as well, the main reason for the name of that selector.

We also note that the calling line is fed battery from the recording-completing trunk circuit at the outward toll switchboard.[10] This typically follows the same arrangement seen in Figure 8 (aimed in the opposite direction).

There is DC on the conductors of the dial intertoll trunk and toll switching trunk, but it does not have any "transmitter current" implications. Its role is totally for signaling. We will be looking into that in detail in a little bit.

Since in the local train battery is fed to the called line from the connector, why in the toll train is it fed from the toll transmission selector?

Note that as a consequence of the relatively-few toll calls per station in this office, there were far fewer toll transmission selectors than toll connectors. The toll battery feed and transmission circuit is more costly than that in the local connector and takes a lot of space (the repeat coils used at the time were quite large). Thus it was more

[10] The odd name of this trunk and its trunk circuit is an artifact of a specific mode of handling toll calls, with which we will not be bothered in this article.

beneficial to locate this more costly circuit in the toll transmission selector.

5 COMBINATION CONNECTORS

It was actually quite common in SXS offices to use *combination connectors*. These could either operate with a local connector "personality" or a toll connector "personality", depending on through which of their two "ports"[11] they were seized by a selector. The concept is shown in Figure 10.

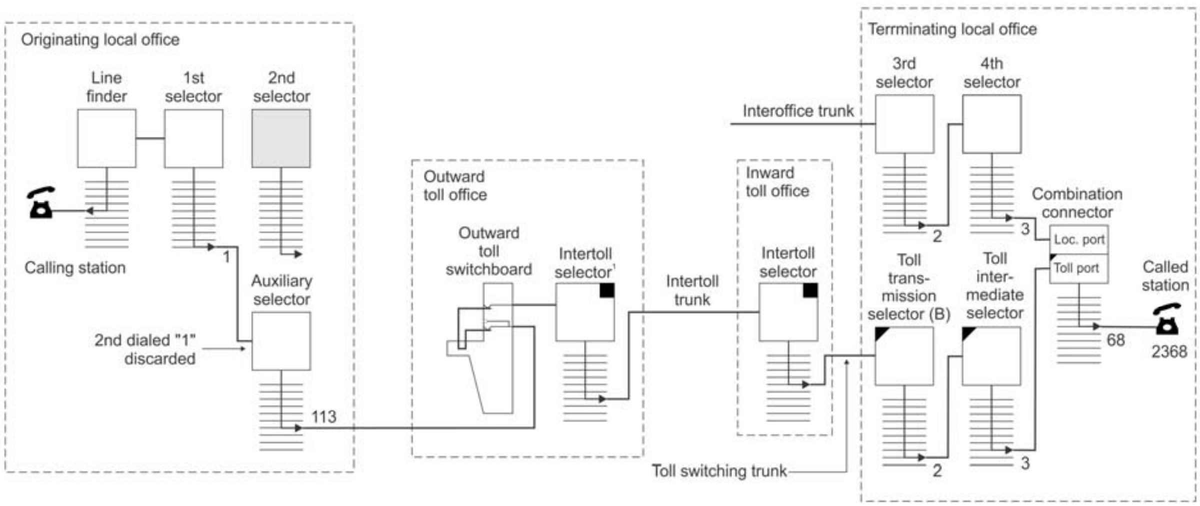

Figure 10. Combination connector

When the switch is seized through either port, it is marked busy at the other port.

The arrangements by which local selectors choose a connector are made so that local selectors will make the subgroup of combination connectors their last choice, thus reserving them, so far as possible, for toll calls.

6 COMBINATION INTERTOLL AND TOLL TRANSMISSION SELECTOR

In some network setups, it is desirable to have the same selector, for some calls, to act like an *intertoll selector* (connecting perhaps to a *toll transmission selector* at the destination office, in another building) and, for other calls, to itself act as a *toll transmission selector*, connecting to toll intermediate selectors in a destination office in the same building. This would allow a smaller number of connectors to be installed for any given combination of local and toll traffic.

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[11] The term "port" was not actually used in telephone industry practice "in the day", but in a modern context it is well descriptive.

Of course, in these two tasks, the technical arrangements are quite different. For example, when acting as a toll transmission selector, the switch must include a battery feed and transmission coupling arrangement; when acting as an intertoll selector, it does not include that, but rather provides a through path for T and R. And there are differences in the signaling and control protocols on the "downstream" side.

These two personalities can be selectively exhibited by a *combination intertoll and toll transmission selector*. The personality in effect depends on the level to which the selector is dialed, under control of a contact on a *normal post contact assembly*.[12]

This assembly provides for contacts that can be operated when the selector is at any of certain levels (this being done by a sheet metal "cam" having teeth for each level that can be bent out to operate a contact when the switch is at that level).

The details of this creature are beyond the scope of this article.

7 STOP DIAL OPERATION

7.1 Introduction

We tend to think that, in the SXS system, as soon as one dialed digit is finished (that is, there have been no pulses for long enough that it is clear there will be no more for this digit), the next digit may be dialed.

This is not exactly so. After the digit is dialed into a selector, the selector must hunt along the ten terminals on that level for an idle next stage switch and, finding one, must "cut through" to it. Then the A and then the B relay in that next switch must operate[13] before that switch is prepared to receive that next digit. The basic general network planning specification requires that (when digit pulse trains are sent by a "sender" circuit rather than by a dial) there be a minimum 600 ms interval (the "interdigital time") between the end of the last pulse of one digit and the beginning of the first pulse of the next digit.

But the system design also relies on the assumption that when the pulse trains come from a dial, the human who is dialing (subscriber or operator) takes a while to "wind up" the dial for the next digit, which

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[12] The name comes from the fact that the contact assembly is mounted on the *normal post* of the switch, a vertical rod whose principal "regular" job is to be the backstop for a lever on the switch shaft so as to establish the "normal" (that is, not rotated) rotary position of the shaft regardless of its vertical position.

[13] Actually, the B relay must be operated long enough ("soaked") that its release time will then be as expected.

will (hopefully) in most cases give a sufficient minimum interdigital time. And if a subscriber consistently got wrong numbers, it might have been suggested that he dial at a bit less energetic pace.

7.2 Call to a panel dial office

We have concentrated here on the assumption that the called station is served by an SXS office. But, during the era assumed for most of the article, many larger cities were served by the *panel dial system*, a very complex “common control” switching system.

There, for an interoffice call that arrives from a “dial pulse” context (such an SXS office), when an incoming trunk is seized, an *incoming sender* must be attached to the trunk to receive the dial pluses. That sender “sends to the switches” the information needed to set up the connection[14]. The sender is then detached from the trunk and becomes available for assignment to another incoming call.

The connection of an incoming sender to the trunk takes a little while (and that period can be prolonged if all the incoming senders happen to be already in use on other connections).

Thus if, as soon as a trunk to a panel office is seized, the dialing of digits (in our case, by the outward toll operator) continued without pause, the first few pulses (or even an entire digit or more) might well be lost, and of course the connection will not be (properly) completed.

There was a parallel situation in calls to other types of switching systems

7.3 Pulsing control protocols

This is in fact a generalized issue in the telephone network as switching systems (both local and toll) more and more became of the “common control” type, in which incoming digits were always received by a sender or register, which had to be attached to a trunk when it was seized. Accordingly, there arose a set of protocols for what may be called “pulsing control”[15]. All of these protocols incorporated the mantra, “Never pulse into an off hook”[16], where “off

[14] The name “register-sender” would have been more apt for this unit, but the name “sender” was used because of the designers’ preoccupation with the unique way the information was “sent” to the switches

[15] Actually, it is commonly called “outpulsing control”. That is because the sending out of digits from a switching machine (not directly from a dial) is typically said to be “outpulsing” (distinguishing it from the capture of arriving of digits, which however is not called “inpulsing”).

[16] There is one obscure exception in a protocol associated with direct distance dialing.

hook" referred to one of the two syates of the (rearward) signaling channel.

The protocol that pertains to our story here is the *stop dial* [17] protocol. It works this way.

When the setup of the connection reaches a point where the system is not yet ready to receive a digit, the distant entity returns the off hook state on the rearward supervisory signaling channel. The near end knows this can't mean that the called station has answered (its basic meaning): the entire number hasn't yet been sent. So it interprets this off hook state as a *stop dial* indication, and it refrains from sending any further digits until the rearward supervisory state returns to on hook.

7.4 In an intertoll selector

In the SXS intertoll train, though, there is a "race condition" problem. Suppose the digit dialed into the selector takes it to a level where there are trunks to a "register-based" system. Once the selector has cut through to the trunk, the panel system will promptly return the off hook *stop dial* signal. (In fact, the trunk will likely return the off hook even when it is not yet seized.) And this stop dial signal will propagate to the toll switchboard, to advise the operator not to dial any more until further notice.

But, after the end of the dialed digit, there is a delay before cut through occurs (while the selector hunts on the dialed level for an idle trunk to the distant system). By this time, the toll operator may well already be winding her dial up for that digit. And some of the pulses of that digit (maybe all of them) will be lost, and the connection will not proceed properly.

Thus, intertoll selectors that might access trunks into panel offices have a special provision, following what is called the *delay dial protocol*.

When the switch goes to a level with trunks to a panel office, a contact on the normal post spring assembly is operated.[18] As soon as the digit that had moved the switch to this level is finished, this contact assembly results in an off hook state being sent to the rear by the selector.

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[17] Although, as seen from the perspective of the entity that is being dialed into, it would be called the *delay dial* protocol.

[18] A separate one from that used to control automatic ringing for ringdown trunks, a feature that the selector might also have.

This lights the cord supervisory lamp at the outward toll switchboard, advising the operator, as soon as practical, not to dial further digits until "further notice".

Then, when an idle trunk to the next stage has been found, and the switch cuts through to that trunk, that ground from this selector is removed. But immediately, there will be an off hook state (its *delay dial* indication) coming from the distant office, so the stop dial indication is continued.

Then, when the distant office is ready for further digits (it having attached an incoming sender), the rearward supervisory state from it is returned to on hook. At the outward toll switchboard, the cord supervisory lamp goes dark, and the operator knows she can resume dialing.

8 CALLBACK AND RINGING CONTROL FUNCTIONS

8.1 Introduction

Various scenarios of handling the wide range of long distance in the varied situations that are encountered place special requirements on the toll completing train.

8.2 Callback

There are several scenarios in which the outward toll switchboard must call the **calling** subscriber. One is to set up a suitable connection from the calling line to the outward switchboard.

Another scenario is this. The outward toll operator cannot advance the connection because, say, all the trunks that might be the next link in the connection are busy. The outward toll operator advises the caller that the call cannot be completed now. She tells him that she will call him back when the call can be completed.

When that "congestion" has been relieved, a "delayed call" toll operator calls the caller (whose number she has on the ticket made by the original toll operator at the start of the call). But if she did this through the **local** completing train of the office serving the caller, the battery feed and transmission circuit for the caller would be that used for local connections, As we learned earlier, this is not desirable for a toll call (which will presumably ensue).

So instead this new outward toll operator calls the caller through the *toll completing train* at the office serving the caller. The toll transmission selector there of course provides a battery feed and transmission circuit worthy of inclusion in a toll connection.

The toll transmission selector (in particular) must be prepared to properly work in this "retrograde" mode.

8.3 Delayed ring

Suppose that on a person-to-person call, the wanted party is not home at the time of the initial call, but her father (who answered) says that she will certainly be home by, say, 3:00 pm.

The toll outward operator asks the caller if he would like to have the call placed then. He says yes.

When a "delayed call" operator goes to set up that follow-on call, to expedite its eventual completion she may, before trying to call the wanted line, call back on the caller's line, but in a way that ringing is not started. Among other things, this makes sure that the caller's line is not busy as this scenario plays out.

When the operator calls the called line, and it is answered, and the wanted party comes to the phone, the operator asks her to wait while the caller is brought into the connection. She then operates a key that makes ringing commence on the connection to the **calling** line. When the caller answers, the operator says, "We have your party on the line." And the conversation ensues.

8.4 Rering

Suppose that a toll call is placed on a "collect" basis, where (with the assent of the called party) the changes are billed to the called subscriber. Suppose that the caller accepts the operator's invitation to learn, after the conversation is finished, how much the charge will be.

Thus, after the conversation ends, the outward toll operator must again get in touch with the called party. She does this on the remnants of the original connection, pressing a key that makes the toll transmission selector again ring the called line.

8.5 In summary

We can see that these "gymnastics" sometimes required in the handling of a toll call require special capabilities in the toll completing train. Most of these actually fall to the toll transmission selector, but the toll intermediate selector has to "play along".

When I discuss the detailed protocols (in Appendix B), that collaboration will be more apparent.

9 A-B TOLL OPERATION

Imagine that for subscribers in Ourtown, calls to Nearville, which is not very far away, are nonetheless, from a rate standpoint, "toll calls". And there are a lot of those "toll calls" made.

Most of these calls do not involve the kinds of complications that may arise in the broader field of toll calls (such as those discussed above in Section 8.

To reduce the cost of handling such calls, and as well to make this some what more convenient for the subscriber, rather than handling these calls through the toll network (as described in great detail earlier), such calls are often handled by a simpler operating method most often technically known as "A-B toll".

This is discussed in detail in Appendix A.

10 ELIMINATION OF THE SEPARATE TOLL COMPLETING TRAIN

Over time, changes in the transmission systems used led to the ability to have a lesser loss on the "interior" of the toll network. This in turn relieved the need to "squeeze the last bit of output" from the telephone set.

In addition, the newer telephone sets (notably the 500-type) provided more consistent output with varying line current.

These considerations reduced the value of an improved battery feed circuit in the toll competing train.

Additionally, the decrease in toll call rates (on an adjusted for inflation basis) decreased the number of toll calls that were made on a "person-to-person" basis (which calls often required some of the special features of the toll completing train).

Finally, the onset and eventual wide acceptance of Direct Distance Dialing further decreased the number of toll calls that were operator-handled and thus which might have required some of the special "gymnastics" that were supported by the separate toll completing train.

As a consequence, starting in I think in the early 1960s, the Bell System moved toward the use of the "local" completing train for both local and toll calls (thus eliminating the separate toll completing train). This led to substantial cost savings in the local offices.

One ramification of this was that toll operators would no longer be able to "re-ring" a party nor use "delayed ringing". As suggested just above, the number of calls requiring either of these tools had greatly diminished. New operating practices were instituted to allow every call situation to be handled without these special tools. For some of these calls, this led to a more labor-intensive process than before, but the overall economic situation was greatly improved by this change.

11 SEIZURE AND PULSING

In the local network selectors (all stages) and connector are "seized" by a DC closure ("bridge") between the tip and ring conductors of the circuit, and digits are sent by a series of "pulses" that are open intervals in that bridge.

But intertoll selectors, and the directly-related type of toll transmission selector, are seized with a what is called a *simplex ground*, and digits are sent by pulses of open on that ground. This matter is described in detail in Appendix B

12 INTERFACES AND PROTOCOLS

In the local network selectors (all stages) and connectors are "seized" by a DC closure ("bridge") between the tip and ring conductors of the circuit, and digits are sent by a series of "pulses" that are open intervals in that bridge.

Typically the trunk from one switch stage to the next (if intrabuilding) comprises three conductors, the ring (R), tip (T), and sleeve). These trunks, if interbuilding, generally comprise only two conductors (R and T)

But in the toll switching system intrabuilding links between successive switches may comprise four conductors (R, T, S, and a fourth conductor, designated SP or C depending on just where we are and what it does. And the protocols for the interaction of the switches differs considerably from that found in the local switch train.

And intertoll selectors, and the directly-related type of toll transmission selector, are seized with a what is called a *simplex ground*, and digits are sent by pulses of open on that ground.

The details of those signaling and control protocols and the uses of the four leads found at a particular interface are covered in considerable detail in Appendix B.

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Appendix A
The A-B toll method of operation

A.1 INTRODUCTION

Imagine that for subscribers in Ourtown, calls to Nearville, which is not very far away, are nonetheless, from a rate standpoint, “toll calls”. And there are a lot of those “toll calls” made.

Most of these calls do not involve the kinds of complications that may arise in the broader field of toll calls Those include the need for a toll operator to re-ring the called subscriber to report the cost of a “collect” call, or to call back the called subscriber but delay ringing, part of the “gymnastics” involved in a “delayed” call, often required for a “person-to-person” call.

To reduce the cost of handling such calls, and as well to make calling somewhat more convenient for the subscriber, rather than handling these calls through the “regular” toll network (as described in great detail earlier), such calls are often handled by an operating method technically known as “A-B toll”[19] [20] (don’t worry yet about what that name means –that will shortly be apparent).

This mode did not include the possibility of such complications as “person-to-person” calls nor calls whose setup was “delayed” for various reasons. In the case that a call could not be completed immediately (owing to, perhaps, the lack of an idle trunk over which to advance the connection), the caller was just advised to “try again later”.

If the caller wanted to make a “”person-to-person” call, the calling instructions in the directory would in effect advise him to use the “regular” mode of toll calling.

The way this mode worked, technically, is described in the sections to follow.

A.2 BETWEEN MANUAL SWITCHING OFFICES

A.2.1 Interoffice calls

In fact, to explain the name “A-B toll”, we need to first briefly review the typical way that interoffice local calls are handled in a wholly-manual switching area. I will work from Figure 11.

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[19] Often styled as “AB toll”. I will, for consistency, use “A-B toll” here.

[20] That term was not necessarily used in “public” documents such as telephone directories. Other terms were often used there to describe this mode of long distance service. That is a matter beyond the scope of this article.

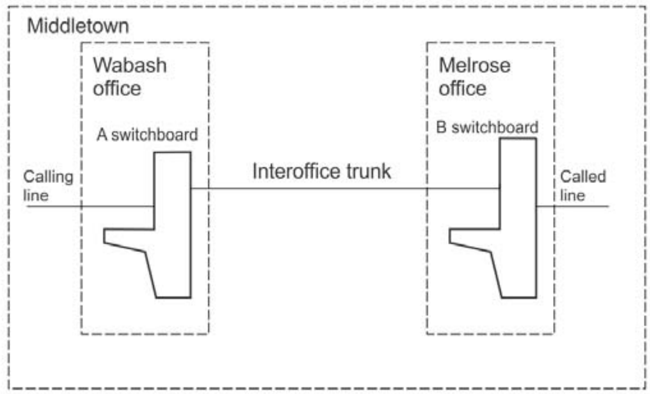

Figure 11. Manual interoffice call

At each of the two central offices, Wabash and Melrose, both in the town of Middletown, there are two switchboards (each typically with many positions), called the "A" switchboard and the "B" switchboard (we see here only one position of each of those at each office).

Suppose the Wabash subscriber wants to call a friend served by the Melrose office (a "not-toll call). When he takes his telephone off hook, an operator at the Wabash "A" switchboard answers and says, "Number, please". He gives that operator the wanted "Melrose" number. She extends the call over an interoffice trunk to the Melrose "B" switchboard, and passes to that operator the wanted number (the line number part only–the Melrose part is obvious). The "B" operator there extends the connection to the desired line, and that line is rung.

A.2.2 Toll call to a distant city

Now if our Middletown Wabash subscriber had wanted to call, for example, a friend in Riverdale, a quite distant city, he would have asked the answering "A" operator for "Long Distance". We see the players in this scenario in Figure 12.

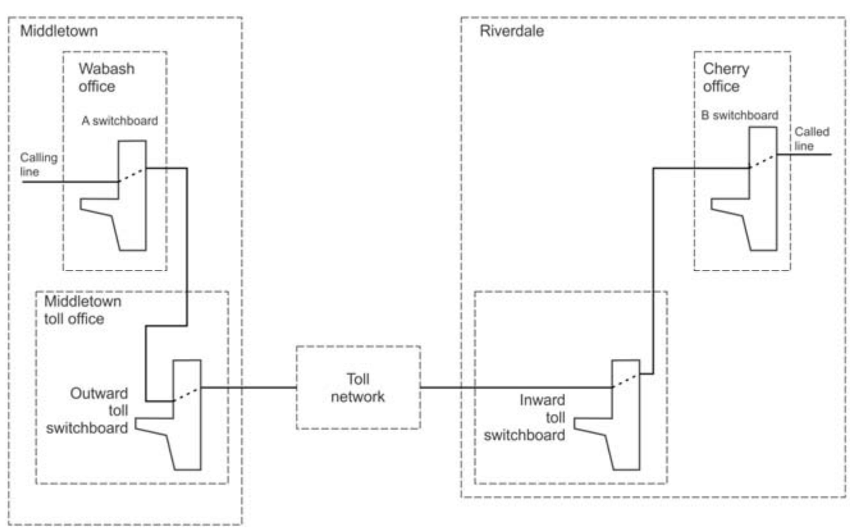

Figure 12. Manual "regular" toll call

The A operator would extend the connection to the appropriate *outward toll switchboard* ("Long Distance"), who would answer, "Long Distance". He would give that operator the city and number he wished to call.

The toll operator would launch the call into the toll network (about which much has been said earlier), the connection eventually reaching the *inward toll switchboard* serving Riverdale. The wanted "Cherry" number would be passed to that operator by the Middletown outward toll operator.

The inward toll operator would extend the connection to the B switchboard at the desired office in Riverdale (Cherry). The B operator would complete the call essentially just as would be done for an interoffice local call.

A.2.3 A-B toll calls

In Figure 13 we see the situation for our next scenario: we finally will see an "A-B toll" call.

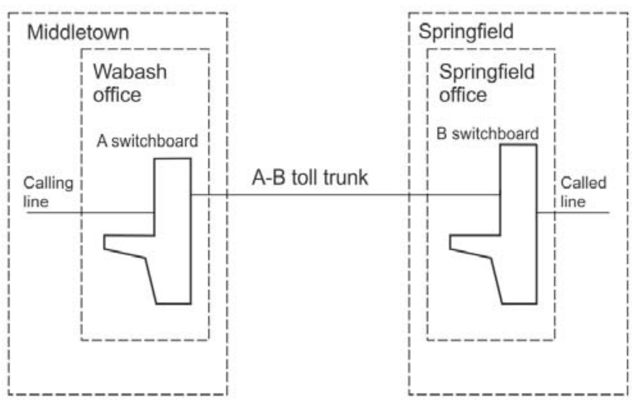

Figure 13. Simple A-B toll call between manual offices

The Wabash caller wants to call someone in Springfield, a town far enough away that this will be a "toll call", but near enough that the "A-B toll" scheme is used.

Based on the calling instructions in the telephone directory for calling numbers in Springfield, the caller does not ask for "Long Distance". Rather, he asks the answering "A" operator for the wanted number in Springfield (giving both the city and the number.

The A operator extends the call over an A-B toll trunk to the Springfield B switchboard (we assume for now there is only one office in Springfield, often the case for the destination cities to which this method of operation is typically used). She passes to the B operator the wanted number. The B operator completes the call to the wanted line.

Note that this looks almost like a manual local interoffice all. The technical moniker "A-B toll" was given to this mode because this involves an (ordinary) A operator and an (ordinary) B switchboard/operator, no "toll" operators being involved.

Differences from a local interoffice call include:

- The A operator makes a toll ticket, with the details of the call, that will be used to bill the caller for it.
- Because the A-B toll trunk was typically quite a bit longer than a local interoffice trunk, it might not have been implemented just as a plain physical pair, as would be used for a local trunk. And as a consequence, the signaling over that trunk might well have been different that that used on a local interoffice trunk.

The B switchboard position involved might be a position in a section of that B switchboard dedicated mainly to completing toll calls.

A.2.4 Tandem operation

In some cases, most efficient use of the A-B troll trunks to a "cluster" of nearby smaller cities is attained with the use of an intermediate switchboard located in the cluster (almost always in the central office of one of the cities in the cluster). We see this "tandem switching" form of A-B toll operation in Figure 14.

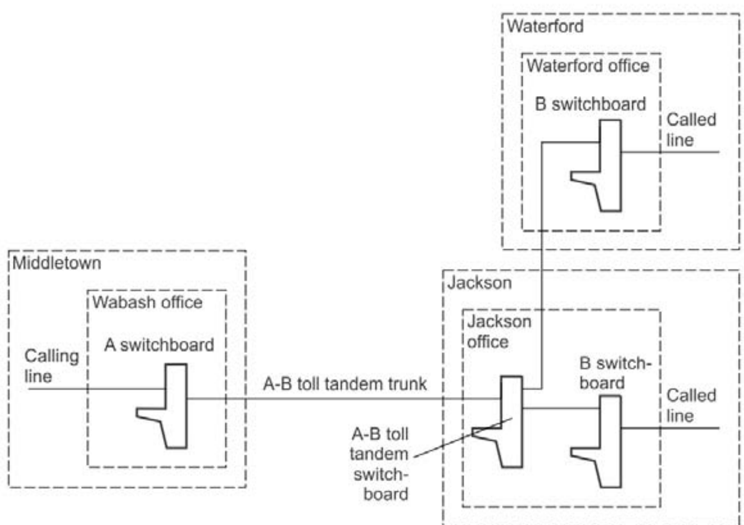

Figure 14. A-B toll tandem switching

Here A-B toll calls from Middletown to either Jackson or Waterford are sent over a trunk in a common group to a manual A-B toll tandem switchboard in Jackson. The operator there can extend the call to the B switchboard in either Jackson or Waterford.

A.3 BETWEEN SXS DIAL SWITCHING OFFICES

A.3.1 "Regular" toll call

In Figure 15, for comparison, we see the overall situation for a "regular" toll call between two SXS dial offices.

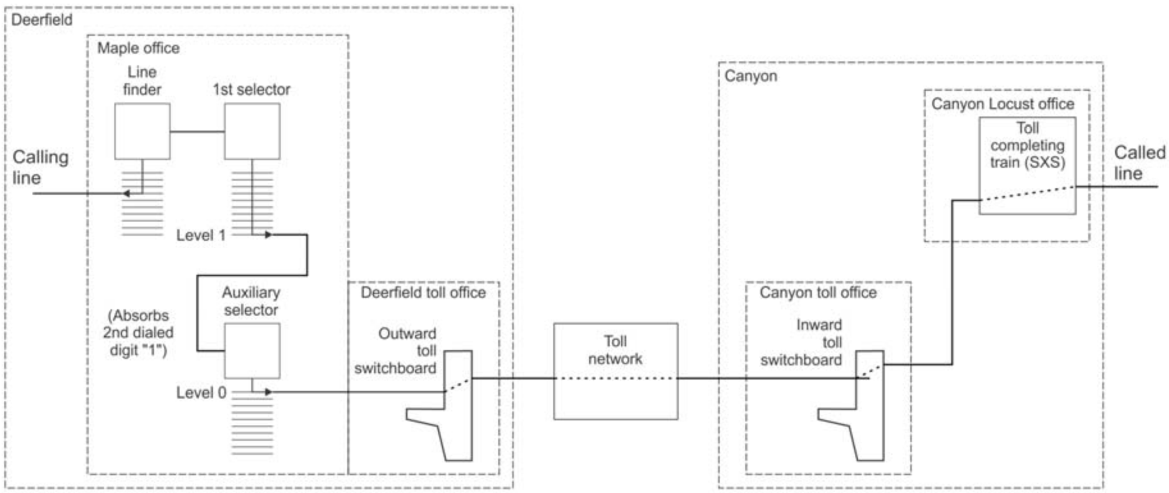

Figure 15. "Regular" toll call between SXS offices

The caller (in the Deerfield Maple office) dials "110" to reach the "Long Distance" operator. (The second dialed "1" is just "absorbed" by the auxiliary selector to save switch stages.)

The outward toll operator (to use the formal name) extends the call through the toll network (many details of which are discussed above) to the cognizant inward toll switchboard.

The inward toll operator extends the call via the *toll completing train* (often called just the "toll train") at the destination office (Canyon Locust), to the called line. (I show that train as just a "block" here for simplicity. We will look more into that switch train in a little bit.)

A.3.2 A-B toll call to a nearby city

In Figure 13 we see the situation of this scenario in a typical form.

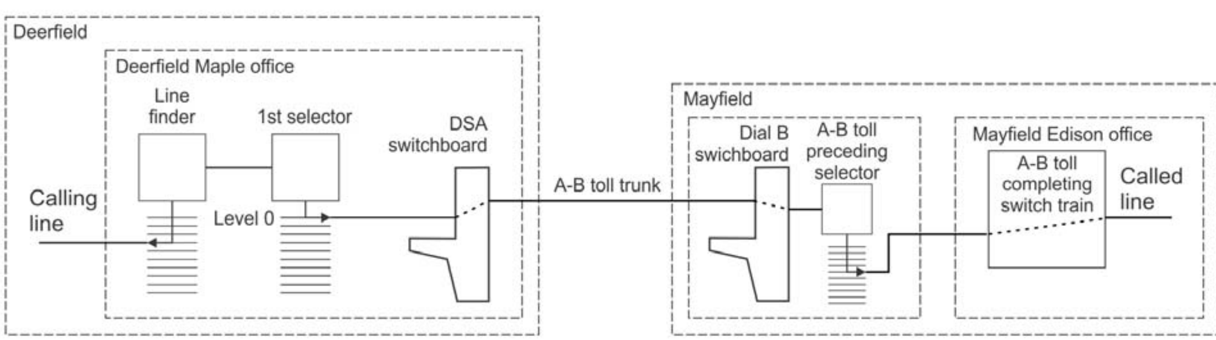

Figure 16. A-B toll call between SXS offices

Here our subscriber in Deerfield (with dial service) wants to call someone in another nearby city, Mayfield (what has more than central office), also with dial service. He dials "0" to reach the "local operator" (formally, the DSA switchboard [21] operator). He tells the DSA operator that city and number. She extends the call over an A-B toll trunk to a dial B switchboard serving Mayfield).[22]

The Deerfield DSA operator passes the desired number to that B operator. By dialing into a *toll preceding selector* (we will shortly see the premise of that name) she extends the connection to the A-B *toll completing switch train* of the Mayfield office involved, and dials the station number into that train.

The Deerfield "DSA" operator makes a *toll ticket*, with the details of the call, which will be used to bill the caller for the call.

We see here why the moniker "A-B toll" again seems apt: the call passes from an "A" operator to a "B" operator (no "toll operators" being involved at all).

The title "toll preceding selector" comes from the fact this switch immediately *precedes* the toll train.

The B switchboard position will very likely be a position in a section of that B switchboard dedicated mainly to completing toll calls.

Note that the toll preceding selector in Mayfield might also allow call to be directed to offices in nearby cities, somewhat paralleling the A-B toll tandem operation between manual offices seen in Figure 14.

A.4 THREE DIFFERENT COMPLETING SWITCH TRAINS

A.4.1 Introduction

Three different completing switch trains are of interest once we take into account the A-B toll method of operation. They are illustrated on Figure 17.

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[21] The original formal name of this switchboard was the "dial system A" switchboard, from which that abbreviation came. It was so-called because it was the closest thing to a "A" switchboard that a dial office had, and its operator provided many of the supporting services which were done, in a manual office, by the A operator. Later, when that historical connection to a real "A" switchboard had faded, the formal name was changed to the "dial service assistance" switchboard (still, conveniently enough, abbreviated "DSA".

[22] Sometimes called a "DSB" (dial system B) switchboard. Its "main" job might have been to complete, through the local completing trains in the various Mayfield dial offices, local calls from manual offices in that same city.

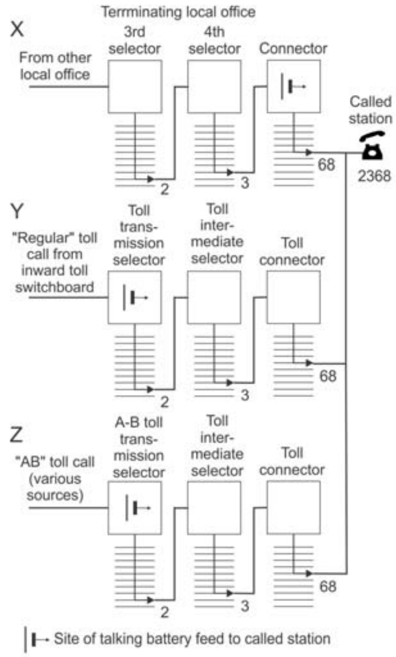

Figure 17. Three terminating switch trains

In this Figure, the battery symbol with the appended arrow serves to remind us of the site of the talking battery feed to the called station in each of these configurations. (The transmission circuit is located in the same place.)

The numbering of the selectors in the local completing train (train "X") will vary with the number of digits in the local numbering plan involved, but in any case we see the last two selector stages.

A.4.2 The local and (regular) toll completing trains

We earlier saw that the completing switch train for ("regular") toll calls (often called just the "toll train") (train "Y" in the Figure) was different from the completing switch train for local calls (train "X" in the Figure).

To review and summarize, the principal reasons were:

a. For transmission reasons, it was desirable in toll calls to have the battery feed to the called station more closely regulated than would be the case with the battery feed circuit (in the connector) used for local calls.

b. Similarly, it was desirable in toll calls to have the transmission circuit (which couples the calling and called ends of the connection) to have lower loss than the transmission circuit (in the connector) used for local calls.

c. Economic considerations favored the siting of the circuits described in a and b above in an earlier switch than the connector.

d. Various operational scenarios required in the overall landscape of traditional toll operation needed special ways of controlling the application of ringing.

e. Best compatibility with the way toll trunks were implemented led to the use, for “regular” toll transmission selectors, of *simplex* seizure and pulsing, rather than the *loop* seizure and pulsing used on local interoffice trunks.

These considerations led to the use of different switches in the completing train to be used for toll calls from those used in the completing switch train used for local calls.

Also recall that the role of the toll connector may be taken by a *combination connector* in its “toll” mode.

A.4.3 The A-B toll completing switch train

We see that train as train “Z” on the Figure.

In A-B toll operation, factors “a”, “b”, and “c” mentioned just above still apply. But as to factor “d”, in A-B toll operation we do not have the special gymnastics sometimes required in the overall landscape of “regular” toll operation.

Thus the A-B toll completing switch train never has to deal with:

- being used by a toll operator calling back the calling party on a prospective toll connection (notably when the call setup is delayed).

- re-ringing either party of a toll connection

- delaying the application of ringing to the calling station when it is connected to on a “delayed” call setup.

So this simplifies the duties of the TTS as used in A-B toll operation.

But there is one new duty of the A-B completing train. Recall that in traditional “regular” toll operation, if the called station is found busy, audible busy tone is not returned. Rather, a “supervisory busy flash” signal is sent over the signaling path, which will cause the cord supervisory lamp for this connection, at the outward toll switchboard, to flash. This advises the operator (even if at the moment she is handling another call) that the called line is busy. She then advises the caller, and they may discuss what to do next.

But the idea was for “A-B toll” to act to the caller just like a local call, except of course for the need to have the DSA operator set it up. The hope was that the DSA operator, having set up the call, could later be little involved (other than to pull down the connection when the conversation was finished).

To that end, it was decided that on a call to a busy station, busy tone should be returned, and the caller would just hang up. But of course the supervisory busy flash signal would be sent as well, in case the operator had to intervene.[23]

So the A-B toll transmission selector (TTS) had to do that. And for both those reasons, it was a different type of switch than a “regular” TTS.

Another difference from the “regular” TTS is that the most common A-B toll TTS uses seizure and pulsing on a *loop* basis, just as for local selectors, rather than the *simplex* seizure and pulsing used on a “regular” TTS. This better fits with the fact that in many cases the A-B toll trunks were implemented with just a cable pair (just like local interoffice trunks).

In any case, the other players in the toll completing train—the *toll intermediate selector* and the *toll connector* (or *combination connector* in its “toll” mode)—were the same as used in the regular toll completing train.

We now see the rationale for the name “A-B toll preceding selector” mentioned in section A.3.2. It is just before the “toll train”.

A.4.4 Battery feed at the originating end

In the basic DSA switchboard, the cord circuit toward the calling line end provides talking battery of the 48 V “regulated” kind, and the cord transmission circuit is if the repeat coil kind. Thus this link of an A-B toll connection is able to do its part from a transmission standpoint.

A.5 USAGE OF THE A-B TOLL METHOD

A.5.1 General

According to an article in the Bell System Technical Journal, in 1915, 47% of toll calls were handled on an A-B toll basis. In 1934 (the last year shown), 64% of toll calls were handled on an A-B toll basis.

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[23] It turns out that there are some real problems arising when sending both a supervisory busy flash signal and audible busy tone, which nonetheless was the norm for all toll network operation once direct distance dialing (which did not involve any operators) came into being. Once direct distance dialing became the most used mode for toll calls, the norm for network became to return only audible busy tone (and not also a supervisory busy flash signal) for a busy line.

Even though for various reasons this mode was mostly used for toll station-to-station calls to “relatively nearby” cities (and was the preferred mode there), such toll traffic was a large fraction of all toll traffic (subscribers were more likely to make a toll call to a nearby city than to a more distant city, owing to the cost difference involved).

A.5.2 Longer distances?

The reference information I have suggests that, generally speaking, the use of the “A-B toll” operating method was limited to calls to relatively nearby cities. Why this limitation?

I have no real ideals. I conjecture that, with regard to longer routes, it was not efficient to have two sets of “long distance” trunks, one for only A-B toll calls (and thus, only station-to-station calls) and one for “all other (mostly person-to-person) calls.

A.6 A DISTINCT SERVICE?

In some cities, during certain eras (Denver in 1912, for example), the telephone company advertised a service, described as a attractive alternative to their “long distance” service, for “station-to-station” (only) toll calls to nearby cities.[24] One advantage given was that the rates for such calls were less than even the “person-to-person” rates for the “regular” long distance service. It was also described as “quicker”.

This service was presumably conducted via the A-B toll method (whose costs were less than for handling the same call via the regular long distance methods, thus leading to the lower rates), and which in fact typically had shorter setup times than for the “regular” long distance methods of operation.

But elsewhere, there was no such distinct “service”. Rather, the A-B toll method of operation was the preferred method for the telephone company to handle person-to-person calls to certain nearby cities.

This “steering” of toll traffic was done by way of the calling instructions in the directory. For long distance calls to certain nearby places, for station-to station calls, the subscriber was told to dial “0” (for a DSA operator); for person-to-person calls, to dial “110” (for a toll operator).

But for long distance calls to other cities, for both station-to station and person-to-person calls, the subscriber was told to dial “110”.

[24] Thanks to John Haralson for initially bringing this to my attention.

Suppose a subscriber desiring to place a long distance call to a fairly-nearby city, a call which the telephone company handled via the A-B toll method, but dials "110" anyway. Likely the outward toll operator he reached, after hearing of the city to which he wished to call, we advise the caller to hang up and dial "0".

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Appendix B
Interfaces and protocols in the intertoll and toll trains

B.1 INTRODUCTION

In the local network selectors (all stages) and connectors are "seized" by a DC closure ("bridge") between the tip and ring conductors of the circuit, and digits are sent by a series of "pulses" that are open intervals in that bridge.

Typically the trunk from one switch stage to the next (if intrabuilding) comprises three conductors, the ring (R), tip (T), and sleeve).

These trunks, if interbuilding, generally comprise only two conductors (R and T)

But in the toll switching system, intrabuilding trunks (called that, even when they are intrabuilding) between successive switches may comprise four leads (R, T, S, and a fourth lead, designated SP or C depending on just where we are and what it does. And the protocols for the interaction of the switches differs considerably from that found in the local switch train.

The details of those protocols and the uses of the four leads found at a particular interface are covered in considerable detail in this appendix.

Simplistically, where the SP (supervisory) lead is provided, it carries to the rear the supervisory *state*, which mainly has to do with whether the called station is off hook or on hook.

Also simplistically, when the C (control) lead is provided, it mainly has to do with control of ringing to the called station.

B.2 SEIZURE, PULSING, AND RELEASE IN AN SXS LOCAL TRAIN

B.2.1 Introduction

For comparison and contrast, we recall that in an SXS local train:

- Battery is fed to the rear (perhaps to the calling line If there is no interoffice trunk in that path) by the last switch that is so far part of the connection.

- A selector or connector is seized by there being a "bridge" between the R and T conductors of its "port".

- Pulsing of a digit (two digits in the case of a connector) into a switch is done by a train of opens in the bridge.

- The connection is held to the rear by the last switch that is so far part of the connection grounding the S lead to the rear. This holds all earlier switches and they pass that ground on to the rear to hold the earlier switches.

- As soon as the connector reaches the called line and if it is found to be idle, ringing is applied automatically by the connector.

- As soon as the called station answers, ringing is stopped ("tripped") and the battery sent to the rear on the ring and trip is reversed in polarity ("reverse battery answer supervision"). This advises any entity to the rear that the called station is now off hook (assuming that there is some entity that cares; often there isn't).

- If the called station than goes on hook, the battery to the rear is restored to "normal" polarity. Again, this is to the benefit of any entity to the rear that cares.

- A completed connection is released only when the calling station goes on hook. This is recognized by the connector, which opens the sleeve lead to the rear (releasing the earlier parts of the train) and itself releases.

B.3 CONTROL OVER THE CONNECTION

B.3.1 Introduction

There is an important conceptual difference in how a completed or partially-completed connection is "held" in toll operation from what is done on a local call.

B.3.2 On a local connection

In the local network, as the connection advances through consecutive selectors and finally to the connector, the furthest switch that had been "set": at any time "holds the baby". it hold ground on the sleeve lead (S) to the rear, which holds the prior switch (and through it, all earlier switches) in their "set up" state. As the connection is completed, that honor advanced to the connector.

When the calling subscriber hangs up, perhaps after having spoken on an established connection, or perhaps after just dialing a few digits, having thus extended the connection partway (perhaps he is unsure about the rest if the number, and has to look it up), the furthest switch in the connection so far (which is at the moment "holding the baby") recognizes that "on hook" from the loss of a bridge across R and T, and knows that the caller wants to end (or abandon) the connection. It removes the ground to the rear on the sleeve lead (thus causing all earlier switches to release, and then itself releases.

B.3.3 On a toll connection

On a toll connection,, as each switch along the building-up connection is seized, the sleeve lead is grounded forward (this initially coming from the outward toll switchboard).

The result is that the outward switchboard holds all switches in their so-far “set up” state. The connection (wholly or partially completed) will stay “up” until the outward toll operator wishes to relinquish it,

Then, she pulls the cord from the trunk jack. This causes the forward ground on the sleeve lead to be removed, This makes all switches in the connection to release.

B.4 INTRABUILDING AND INTERBUILDING TRUNKS—THE BASICS

The interfaces shown (comprising three or four conductors) are used just as we see them on trunks between two consecutive switches if those switches are in the same building. And I will at first describe the working of the trunks as if that were true in all cases.

But in the *intertoll train*, the preponderance of intertoll trunks run between different buildings (to say the least–these trunks may be hundreds, or even thousands, of miles in length). And in fact, trunks from say, a *toll preceding selector* to a *toll transmission selector* may run between different buildings.

In that case it is not workable to carry all four conductors of an interface for that whole journey. In fact, the transport of such a trunk may be over one channel of a multiplex system. Or earlier, it might have been over a “repeatered” (amplified) set of physical conductors.

In such a case, one way or another there is established in each direction, for each trunk. a binary signaling channel (like a telegraph channel). All signaling has to be done over those.

So in the case that one of the interswitch trunks suggested by the above Figure is actually transported over some distance, at each end there has to be logic circuitry that “translates” the signaling dialog conducted over the three or four interface conductors into messages that can be carried over a single binary channel in each direction.

After we have learned of those dialog protocols between the switched, I will return (in section B.14 to this topic and show how the one language is translated into the other.

B.5 WHERE ONE TRAIN STOPS AND THE OTHER BEGINS

It is fairly clear that an intertoll selector is part of the *intertoll (switch) train*, and a toll connector is part of the toll *completing train*. But where does one stop and the other begin? In particular, the citizenship of a *toll preceding selector* seems as if it might be in some doubt.

We get a clue from the SD- drawing numbers shown for some of the switches. Under the Bell Telephone Laboratories drawing system, drawings for the step-by-step system overall have drawing numbers in the SD-3xxxx series (even for switches used in local step-by-step offices specifically for toll operation.

But toll stuff (of whatever kind (other than that which is part of a "local" SXS office) has drawing numbers in the SD-5xxxx series. And as we see that on the drawing, this confirms that the doctrine is that a *toll preceding selector* is part of the *toll (competing) train* rather than part of the *intertoll train*.

B.6 SIMPLEX SIGNALING

In the interfaces shown on the Figure as comprising the R, T, C, and SP leads, seizure of a selector (or TTS) is not done by placing a DC "bridge" across the T and R leads (as would be the case in a local switch train). Rather, it is done by essentially grounding both T and R from a DC standpoint. Figure 18 shows the circuit principle involved.

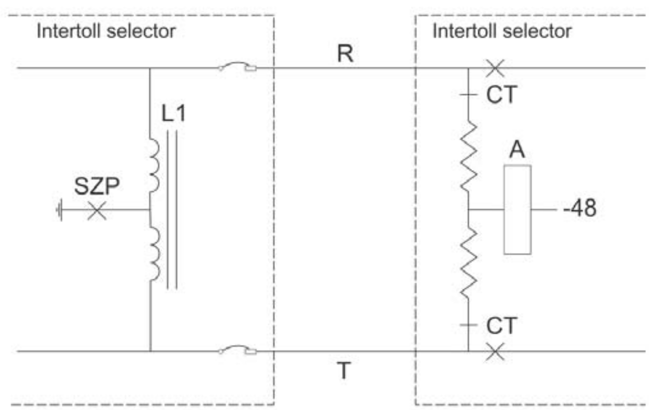

Figure 18. Principle of simplex ground signaling

This is a convention taken from the way signaling states were at one time sent though a long trunk carried by a physical pair, known as "simplex signaling", and that term is used here as well.

Here, we imagine that the seizure of the successive switches of the train, and the pulsing to set those switches, propagates from the outward toll switchboard. We see in the Figure when this is due to propagate from one intertoll selector into a subsequent one to which it has connected.

There, a hypothetical relay contact designated SZP (seizure/pulsing) does this. The ground is applied at the centertap of inductor L1, and thus, from a DC standpoint, is applied to both T and R. The inductance prevents the speech signals that will later appear at this point from being ”shorted out” by this DC connection to both T and R.

At the intertoll selector that is currently “at the point of the spear”, this simplex ground is “picked up” for its A (seizure and pulsing) relay from the center point of an inductor connected to T and R.

B.7 MAP OF THE BATTLE ZONE

To help follow the action in the following sections, Figure 19 shows several kinds of switch that can be involved in the *intertoll train* and the *toll train* (the latter more clearly described as the *toll completing train*). It shows the situation for both the “regular” and “A-B” modes of operation. (The “A-B toll” mode is discussed in Appendix A.)

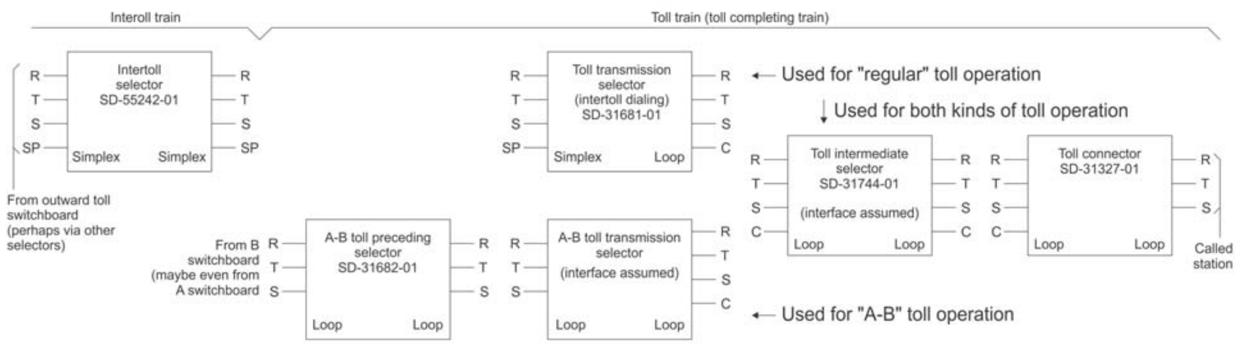

Figure 19. Intertoll and toll train switches and their interfaces

For many of the switch types, I have included the number of the Bell Telephone Laboratories SD (circuit schematic) drawing for a typical switch of that type. This is mainly for my own use, to help me keep track of what is going on here. But note that where no SD drawing number is shown, I do not have that drawing for a typical switch of that type, so the interface it is shown as having is per my assumption.

We see that, as described in the body of the article, the *toll intermediate selector* and the *toll connector* (or the *combination connector* operating in its “toll” mode) are the same for both “regular” and “A-B” toll connections.

B.8 INTERTOLL SELECTOR OPERATION

B.8.1 Seizure

Seizure of the selector is done by a simplex ground, typically originating at the trunk circuit at the outward toll switchboard and perhaps having been passed, transparently, through earlier selectors, which, of course, have cut through.

The simplex ground operates the A relay. The A relay operates the B relay (slow release) in the familiar way[25]. The B relay grounds the incoming sleeve lead. This ground "holds" the prior switch in the toll connection (and thus all prior switches) until the connection is released by the outward toll operator.

B.8.2 Pulsing

Pulsing (sent from the dial at the outward toll switchboard) arrives as periodic removal of the ground from the simplex path. This releases the A relay for each pulse. The entire operation otherwise proceeds essentially as for a local selector.

After the dialing of the digits is completed, the switch autonomously steps in the rotary direction, hunting for an idle switch at the next stage at that level.

B.8.3 No idle following selector found

If there is no idle next-stage selector on the level indicated by the received dialed digit, the switch continues to step in the rotary direction until it has passed all bank terminals. This operates the *11th step rotary* contact set. One contact there stops the rotary stepping. Another applies ground interrupted at 120 IPM on the rearward SP (supervisory) lead. This is passed by the trunk circuit at the outward toll switchboard to the cord circuit in use for this call. That will cause the supervisory lamp of the cord circuit at the outbound toll switchboard to flash, following that 120 IPM pattern, telling the operator that the connection cannot be completed.

B.8.4 Cut through

When an idle next-stage selector is found on the dialed level, this selector, via its cut through relay, (CT in Figure 18), takes the incoming ring and tip off the simplex inductor and connects them to the switch wipers and thus to the following switch. The A relay releases. Shortly, the B relay releases.

The CT relay remains operated as it is held to the sleeve, which is still grounded from earlier in the train, even though the B relay has released and removed the ground it had placed on the sleeve. The CT relay operated prevents the switch from releasing, even though the B relay had released.

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[25] In step by step switches, the relays are invariably designated based on their physical location on the switch "chassis"; the designation does not suggest function. And in the vast majority of SXS selectors and connectors, the A relay is the seizure relay and the B relay is its slow release follower. Thus in a generalized discussion, it it common to speak as if those designations imply those functions, and I will often do so here.

B.9 AT THE TOLL TRANSMISSION SELECTOR

B.9.1 Seizure and pulsing

The end of the intertoll train is a toll transmission selector (TTS). It is also the beginning of the toll completing train (often just called the "toll train". Seizure and pulsing into that switch work just as described above for intertoll selectors. The remainder of its operation is quite different.

B.9.2 Cut through

It there is an idle trunk to the next stage switch (a toll selector), cut through occurs, in this case meaning that a resistive bridge is placed across the T and R leading to the next switch to seize it, in essentially the way that a selector in the local train is seized.[26] However, the sleeve S lead to the next stage is also grounded.

B.9.3 No idle following selector found

If there is no idle next-stage selector on the level indicated by the received dialed digit, the switch continues to step in the rotary direction until it has passed all bank terminals. This operates the *11th step rotary* contact set. One contact there stops the rotary stepping. Another causes ground interrupted at 120 IPM through a 500 ohm resistor to be applied the rearward R lead.

The TTS converts this to pulses on the rearward SP lead. By way of the signaling provisions of the trunks and intervening selectors, this passes to the trunk circuit at the outward toll switchboard, which will cause the supervisory lamp of the cord circuit at the outbound toll switchboard to flash, following that pattern, telling the operator that the connection cannot be completed.[27]

B.10 AT AN INTERMEDIATE TOLL SELECTOR

If the next switch is a toll selector, when idle it presents battery across the T and R through windings of a A relay (just as in a local selector). When the switch is seized, the resistive bridge across T and R, coming from the TTS, operates the A relay, which operates the B relay (slow release).

So we note that while seizure and pulsing ahead of the TTS is on a simplex basis, after the TTS it is on a loop basis.

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[26] Note that this is different from what we had in the intertoll portion of the train, where seizure and pulsing was by simplex ground.

[27] This is traditionally called a "reorder" signal, as it suggest to the operator that she should attempt (immediately) to re-make (that is, to "re-order) the connection.

Pulsing takes place just as for a local selector, and trunk hunting also operates in essentially the same way.

B.10.1 No idle following selector found

If there is no idle next-stage selector on the level indicated by the received dialed digit, the operation is just as described in section B.8.3.

B.10.2 Cut through

It there is an idle trunk to the next stage switch (likely a toll connector), cut through occurs, in this case meaning that (just as in a local selector), the T and R are taken off the A relay (which releases) and extended forward through the selector wipers to the following switch. The S lead going to the next switch is also grounded. The cut through relay locks to the S lead.

When the A relay releases, it releases the B relay, which removes the ground the B relay had applied to the S lead. But the S lead is also grounded forward from the TTS, and so the cut through relay stays operated, keeping this selector "up".

B.11 AT THE TOLL CONNECTOR

B.11.1 Interface

The interface between the toll intermediate connector and the toll connector comprises the familiar ring (R), tip (T), and sleeve (S) leads, plus a fourth lead, C. Simplistically, the C lead is used to control ringing.

B.11.2 Seizure

When the toll connector is idle it presents battery across the T and R through windings of a A relay (just as in a local connector). When the connection reaches the toll connector, the bridge across T and R (from the TTS), operates the A relay. Here, there is no slow release follower of A (what would often be in a local connector designated B). But the grounded S also reaches the connector, and will hold it "up".

When the connector is seized, the ring trip relay (will call it "RT"[28]). is operated, and it locks to the C lead, which is grounded at this time (at the connector, where C is for the moment tied to S, and the incoming S is grounded.

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[28] In fact, in the most common toll connector, it is this relay that is designated "B" (owing to its physical location).

Pulsing of two digits follows generally the same concept as for a local connector.

B.11.3 Called line found

When the connector arrives at the called line, the connector removes the ground to the rear on the C lead. At the TTS:

- The ungrounding of the C lead from the connector releases a slow release relay at the TTS. When it releases (after a brief period), the TTS grounds the C lead forward. It is now the TTS that controls the C lead between it and the connector.

- The incoming T and R (likely from an intertoll selector) are connected to one side of a transmission repeat coil (the simplex connection to the A relay of the TTS now being picked up through its windings).

- The resistive bridge across T and R forward is removed.

- The downstream side of the transmission repeat coil (with a battery feed circuit) is connected to the T and R forward.

At the connector, the incoming T and R leads are taken off the seizure relay (A) and extended forward to potentially reach the wipers and thus the called line; that path is, however, not now complete.

B.11.4 Called line busy

If the called line was found to be busy, the connector applies ground pulses at 60 IBM through a 500 ohm resistor to the R lead to the rear. At the TTS, this operates the battery feed relay there on the same pattern. The TTS repeats that pattern rearward as ground pulses on the rearward SP lead. The ultimate result is that the cord supervisory lamp at the outward toll switchboard flashes in that same pattern, advising the operator there that the called line is busy.

B.11.5 Celled line idle

At the connector, the incoming T and R leads are extended forward toward the wipers and thence to the called line.

When the connector removed ground from the C lead, the RT relay is released. In its released state, ringing is applied, though the “trip” winding of RT itself (which will detect the flow of DC in the line when the called station answers).

B.11.6 Answer

When the called station answers, the ring trip relay, RT, operates, stopping the ringing. It locks operated to the C lead, which is now again grounded (from the TTS). RT also completes the path from the incoming T and R to the wipers (and thence to the called line).

The battery provided by the TTS forward on T and R extends through the toll selectors and, now, through the toll connector to the called line and thence to the called station.

As that station is now by definition off hook, current flows in this path and operates the battery feed relay at the TTS. This causes the TTS to ground the rearward SP lead. As a result, the supervisory lamp in the cord circuit at the outward toll switchboard goes dark.

B.11.7 Called station goes on hook

If the called station goes on hook, the current in that path ceases, which causes the release of the supervisory relay at the TTS. The TTS removes the ground from the rearward SP lead. This is conveyed rearward over the signaling arrangements of the trunks and intervening selectors. At the outward switchboard, this causes the supervisory lamp to light, alerting the operator than the called station had “hung up”.

B.11.8 Release of the connection

If the outward operator pulls the cord from the trunk jack, the trunk circuit opens the S lead forward, which releases all the intertoll selectors.

When this process reaches the TTS, the TTS removes the ground from the forward sleeve, releasing any further selectors and the toll connector. And the TTS itself releases. *Finita est*.

B.12 RERING

In some scenarios, after a toll conversation is competed, the outward operator will need to speak again with the called subscriber (perhaps to advise him of the cost of the call when it is to be billed on a collect” basis).

In such a case, when the outward operator’s cord supervisory lamp lights, indicating that the called station has gone on hook, she operates her ringing key for the cord. The result is that the trunk circuit at the switchboard removes from the T and R the simplex ground that is one aspect of the “seizure” signaling.

Of course, before the connection has been set up, such a brief retraction of the seizure signal would be interpreted as a dialed digit of “1”. But the TTS knows that we are beyond that phase, and so it responds to that brief interruption by sending an brief open forward on the C lead.

At the connector, this results in the release of the RT relay, which recommences ringing. The rest of the process is just as we saw at the beginning of the call (section B.11.5 *et seq*).

B.13 DELAYED RINGING

We saw in section B.11.5 that once the toll selector has reached the called line and it is idle, ringing starts promptly.

In some scenarios[29] it is desired to make a connection to a line but not start ringing until the toll operator calls for it. In these situations, the path to the toll connector is through a different type of TTS (in fact, the kind I call type "A", as seen in Figure 4).

When the toll connector reaches the called line and finds it idle, it (just as we saw above) advises the TTS by removing ground from the rearward C lead.

But, here, rather than the TTS delaying a short while before putting its own ground back on the C lead (which we saw above releases the RT relay at the toll connector and causes ringing to start), this kind of TTS applies its own ground to the C lead "immediately". (There is a very short gap in the ground on the C lead, but the RT relay is slow release and so does not release when this occurs.)

At this time, the TTS advises the calling operator, by a change in supervisory state[30] (lighting the cord supervisory relay for the first time in this kind of call) that the called line is ready to be rung.

When the operator does want the called line rung, she sends ringing signal into the TTS. The TTS then, for a short period, removes ground from the forward C lead for a short time. This releases the RT relay at the toll connector, which starts the ringing of the called, line. The rest of the process proceeds as described above in section B.11.5.

B.14 INTRABUILDING AND INTERBUILDING TRUNKS–DETAILS

In the *toll train*, almost always all the switches are located in the same building. The "trunks" leading from one selector to the next, or to the toll connector, comprise four "local wiring" leads, T, R, S, and C, whose functions will see shortly.

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[29] Description of the reason for these scenarios, albeit fascinating, is beyond the scope of this article for reasons of conciseness.

[30] The supervisory signaling between the switchboard and an "A" type TTS is a bit tricky, but we need not here be concerned with its electrical details.

In the *intertoll train*, there are in some cases interswitch “trunks” that also run between selectors of successive stages in the same building. These also comprise four “local wiring” leads, T, R, S, and SP.

But the preponderance of intertoll trunks run between different buildings (to say the least - these trunks may be hundreds, or even thousands, of miles in length).

Such a trunk may be transported by a variety of transmission systems. All these systems (at least as we may find them in this context) provide, in addition to the speech signal transmission path, two two-state signaling channels.

Because one of the classical roles of such generalized signaling channels (in particular, the one that is rearward in a certain situation), was to indicate to a calling operator the *on hook* vs. *off hook* state of the called station, the two states of these generalized signaling channels (in either direction, regardless of the function) are always spoken of as “on hook” and “off hook”.

In order for such a transmission facility to accommodate the control and signaling operations of an intertoll trunk, there must be at each end what I have (for simplicity’s sake) here *called trunk terminating equipment* (TTE). Figure 20 shows this.

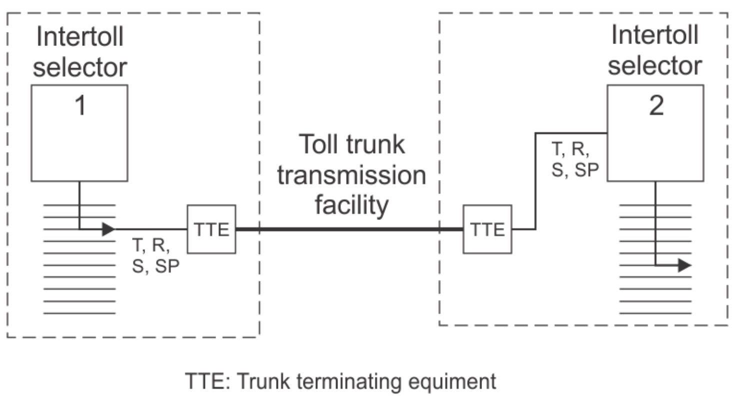

Figure 20. Intertoll train—interbuilding intertoll trunk

One of the jobs of the trunk terminating equipment is to transform the “language” conveyed over the T, R, S, and SP leads from the toll selector into a language that can be conveyed with only a single two-state signaling channel in each direction and vice versa. We will see this happening as we go.

The table of Figure 21 gives a basic description of this transformation for most of the “vocabulary”.

Action	Over an intrabuilding trunk (T, R, S, SP)	Over an interbuilding trunk
Seizure	Simplex ground on forward T, R; ground on forward S	Off hook on forward signaling channel
Pulsing	Interruptions of the simplex ground	On hook pulses on forward signaling channel
Called station busy	60 IPM ground pattern on rearward SP	60 IPM pattern on rearward signaling channel
Called station answers	Ground on rearward SP	Off hook on rearward signaling channel
Called station hangs up	Open on rearward SP	On hook on rearward signaling channel
Rering	Momentary open on forward S	Momentary on hook on forward signaling channel
Release (from operator)	Open on forward S	On hook on forward signaling channel

Figure 21. Signaling transformation for intertoll trunks

B.15 OPERATION WITH RINGDOWN TRUNKS

B.15.1 Introduction

In the era in which the long distance network first emerged, the preponderance of cities were served, for local service, by manual switchboard systems. But later, the long distance network as I described it above was predicated on the preponderance of subscribers being served by "dial" local offices. We in particular, because of the context of this article, have generally presumed that the local offices used SXS equipment.

But of course during the era I have presumed there were still many cities still served by manual switching systems.[31] And thus the "switched" toll network had provisions for completing calls to stations in those systems.

B.15.2 Ringdown trunks

During the early evolution of the telephone network, when all switching was done by manual switchboards, trunks between central

[31] The author had the privilege of attending the dismantlement of the last Bell System manual central office in New Jersey in the mid 1960s.

offices typically were operated on a *ringdown*[32] basis. The operator at the originating office plugged a cord into the jack for the trunk and operated the ringing key for the cord. This sent over the trunk a burst of ringing current, the same as would be used to ring a station on a subscriber line (perhaps 90 V AC at 20 Hz).

This signal was detected at the distant end of the trunk and (in the "modern" form) lit a lamp above the trunk jack, alerting the operator that there was a call coming over the trunk.

In the toll network as I describe it in this article, in many cases, the trunk over which an intertoll switched toll call was taken to a manual local office for completion operating on a ringdown basis.

B.15.3 Ringdown trunks from an intertoll selector

Assume that the routing of a toll call to a certain manual local office called for a certain intertoll selector seizing a ringdown trunk to that office. Intertoll selectors that may have to do that are augmented by a *selector trunk circuit* just before them (essentially, an "outboard front end" for the selector).

These selectors are equipped with a *normal post contact assembly* (see footnote 32). For the levels on which manual ringdown trunks appear (this selector can in general also access "dial" trunks to dial local offices, on other levels), the normal post contact is operated, and as soon as the selector cuts through to the trunk, it causes ground to be placed on a control lead (RD, for ringdown) that runs rearward (along with T, R, S, and SP) to this trunk circuit. This advises the trunk circuit that this is a ringdown trunk that is being dealt with.

This causes the trunk circuit to send forward (through the selector proper) an approximately two-second long "ringing control signal" (battery through 300 ohms on the SP lead, a forward use of a lead that normally is used in the rearward direction).

At the trunk circuit at the near end of the ringdown trunk proper (the circuit to which the selector actually connects though its wipers), this is converted to the "in the speech band" version of ringing signal that was used on "later" ringdown trunks, typically 135 Hz or 1000 Hz modulated at 20 Hz.

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[32] The term traces it origin to an early practice in manual switchboards, in which the arrival of ringing voltage (from a line or trunk) operated a relay-like device (a "drop") associated with the line or trunk jack. This caused the release of a little black "flag", which fell **down** (mind that word) on a hinge, uncovering shiny metal beneath, a visual signal to the operator of a service request (from a line) or call (from a trunk). It was from the behavior of this "flag" that sending ringing voltage over a trunk was spoken of as "ringing **down** the trunk". This then lead to trunks that were operated by sending ringing voltage being called *ringdown* trunks.