Electronic Voting System Failure

November 2023 Special Town Meeting

Executive Summary

The Turning Technologies electronic voting system appeared to have failed at the November 13, 2023 Special Town Meeting. The recorded response rate fell below the limit of 90% established by the Town Moderator, Alan Wilson. Mr. Wilson appointed a committee of town residents with various areas of technical expertise to investigate the failure. After a review of the events leading to the failure, the behaviors of the system, and a variety of possible failures, the committee concluded with high confidence that the cause of the failure was a misconfiguration of the voting computer and the remote receiver. The misconfiguration caused a USB receiver plugged into the voting computer at the podium to receive votes rather than "remote" receiver in the center of the room. The misconfiguration was due to an undocumented behavior of the Turning Technologies system, which caused the remote receiver to switch away from the channel used by the voting system. The committee is also confident that going forward, the electronic voting system will be reliable if installed and tested according to the protocols in this report.

Problem Statement

The Turning Technologies voting system has been used in the past with mixed results. Some years it worked well, but twice, when voters sat in two separate rooms, the system failed to register votes in the second room. To detect a similar occurrence, the moderator established a policy that any time when the number of recorded votes fell below 90% of the number of registered voters present, the vote would not be valid and the meeting would revert to voting by voice or show of hands with voting cards, counted by the tellers.

At the November 13 Special Town Meeting, the two test votes and the first two formal votes met the 90% threshold, but the third formal vote did not. At the same time, several Town Meeting voters announced that their handsets were not responding as expected. The moderator recessed the Town Meeting to allow voters to exchange problematic clickers, but when the meeting resumed, the system failed to meet the response threshold, and the moderator chose to revert to hand-counted votes.

At the meeting, it appeared that most of the voters who exchanged their handsets were seated or standing at the end of the meeting room furthest away from the podium. An informal poll on Facebook also indicated that the problem was almost exclusively in the back half of the meeting room.

Committee Members

The members of the committee were:

- Jim Starkey, chair, is a database system architect and serial software entrepreneur.
- Lee Spence, Ph.D., has 50 years of work on radar and communication systems.

- Kurt Melden has 35 years design network on communication systems and was formerly Chief Scientist of Juniper Networks.
- Bob Moffet has provided AV support for Town Meetings since 2020, including radio frequency coordination for various RF devices.

Also participating were:

- Alan Wilson, Town Moderator
- Ann Harrison, Chair, Select Board
- Tiffany Marletta, the Town's Communication Coordinator, runs the voting system at Town Meeting

The Town Clerk, Dianne Bucco, who has formal responsibility for the voting system, declined to participate in the investigation.

Description of Voting System

The voting system consists of

- A laptop computer on the podium, with Turning Technologies software installed. The software tallies final votes, article by article and maintains a log of all communications between the handsets and the software.
- A pair of "receivers",
    - A local "receiver" plugged directly into the laptop computer ("the USB receiver").
    - A remote "receiver" in the middle of the room ("the remote receiver"). The remote receiver connects to the voting computer through a USB to CAT5 stub at the voting computer, a generic CAT5 cable supplied by the school, and a CAT5 to USB stub at the receiver itself.
- Aproximately 600 handsets (aka clickers). Each handset has a ten digit keypad, an LED, and a small screen.
    - Each handset has a unique serial number used for communication with the voting receiver printed on the back of the handset. The serial numbers of handsets owned by the town are registered with the voting software. The voting software ignores responses from non-registered handsets.
    - To vote, a Town Meeting voter pushes 1 for "Yes", 2 for "No", or 3 for "Abstain". If a voter pushes other numbers, that vote is logged but ignored.
    - A voter can push buttons several times during the voting period. The voting software records only the last message from each handset, but logs all transmissions.
    - After a voter presses a number, the handset receives an acknowledgement that causes the LED to flash green and the screen to show the number that was pressed.

The handsets and receivers are, in fact, transceivers that send and receive messages. Each handset and receiver can be set to one of approximately 80 channels; the town uses channel 72. All handsets were tested and set to channel 72 before the meeting. Both the local USB and remote receivers were also set to channel 72.

Investigation Plan of Attack

The committee initially brainstormed on possible problems. The list included:

1. Insufficient radio bandwidth to support 500+ handsets.
2. Attenuation of the RF communication by voters in the audience.
3. Insufficient power for the USB extender.
4. Insufficient range for the remote receiver.
5. Validity of the 90% response threshold that the Moderator established.
6. A coordinated voting scheme to force an article to a hand-counted vote.

We decided to investigate each of these by:

- Buying a sacrificial handset on EBay for destructive testing.
- Meeting as a group to
    - familiarize ourselves with the hardware and software in various configurations,
    - evaluate the distance limitations of the hardware,
    - investigate the behavior of the handsets when operated near the extreme of operating distances.
- Having the Moderator ask about response rates in similar towns using the Turning Technologies system.

Reconstruction of Events

As best as we have been able to reconstruct, the events leading up to Town Meeting were:

1. The system was initially set up in the Memorial School combined gymnasium and cafeteria with the remote receiver in the middle of the room connected to the voting computer by the USB extender and cable.
2. During setup, the voting computer was not receiving signals from handsets. The local USB receiver was plugged into the voting computer to see whether the system was generally working, which it was.
3. Checking the remote receiver showed that it did not display the green LED indicating that it was live, which suggested that the CAT5 cable between the voting computer and the remote receiver was not working.
4. The CAT5 cable between the ends of the USB extender was replaced and the green LED on the remote receiver appeared.
5. The system was tested again and was thought to be functional.

Handset Analysis

The Turning Technologies clicker and receiver design is closed source. We can, however, infer how it likely operates from several well documented Nordic (chip provider) reference designs and application notes.

It is a single chip processor core plus RF data transceiver working in the 2400 MHz ISM (Wi-Fi/Bluetooth) band.

It has a high-speed duplex protocol with collision avoidance (not collision detection). It is not evident that the system encrypts traffic, but probably is so, as the chip has encryption built in.

The clicker operation includes an end-to-end confirmation of a "vote" from each clicker. If a clicker does not receive an acknowledgment from the receiver, it will retry after some algorithmic backup time. The LEDs on the clicker reflect the state of that clicker's vote.

Based on testimony from the Town Meeting, people near the back (furthest from USB receiver) experienced most of the problems. The ISM band is regulated and devices have emissions compliance. Turning Technologies has been certified. However, there is no coordination of usage by site, that is anyone can use any number or type of ISM devices in a site.

Each smartphone has two ISM band transceivers for Wi-Fi and Bluetooth. With a Town Meeting of 300, there are likely 600 additional interfering devices, on top of the School's Wi-Fi access points, which run at much higher power than the clickers and smartphones.

It is not surprising that distant clickers might not get acknowledgments under such a condition.

Informal Testing

We measured the power consumption of both the USB receiver and the remote receiver configured with the USB extender. The remote receiver drew approximately twice the current of the USB receiver but less than 10% of the USB current specified by the USB standard, ruling out the power hypothesis.

The committee also analyzed the raw logs produced by the Turning Technologies logger, looking for any suspicious voting patterns. None were found. “Voters” were identified by the clicker number, not by name or any other personal identification. We found :

- Many instances of multiple votes, which is completely permissible as the voting software considers only the last number pushed.
- Voters who selected numbers 4 through 0 that were ignored by the voting software.
- Voters who came late and stayed for the duration of the session.
- Voters who came early and left before the session ended.

Other than late comers and those who left early, a relatively small number of voters voted on some questions and not on others, suggesting that while voters were not always receiving vote acknowledgements, it seems likely that their votes were nevertheless counted. There was no observable pattern to voters who skipped one or two votes.

The committee investigated the behavior of the voting system configured with two receivers. We discovered that, contrary to information provided by Turning Technologies, the voting system would not accept two receivers configured on the same channel. Specifically, if one receiver was plugged in and operating on channel 72, and a second receiver also configured for channel 72 was plugged in, the software would automatically (and silently) reassign the second receiver to another channel. We subsequently learned the Turning Technologies voting system was designed to work with multiple receivers on different channels, but does not allow multiple receivers on a single channel.

We tested the system range by dangling the remote receiver out a window having Ms. Harrison walk down the driveway until the signal was lost. We discovered:

1. The system worked reliably up to approximately 200 feet.

2. When a handset approached the maximum distance, it would take longer to get a "vote received" response. At a slightly longer distance, multiple clicks might be required to get a response. Sometimes the handset would display the choice correctly but not illuminate the green LED on the handset.
3. However, handset choices were recognized and received by the voting computer even when the handset was behaving in extremis and even after the handset was receiving no response. We did not test the maximum range for the system to receive a vote.
4. Effective range was drastically reduced when there was a solid wall between the handset and the receiver.

Formal Testing in Memorial School

The committee reconvened in the Memorial School gymnasium/cafeteria on December 29, 2023 during winter break so no students were present. The configuration was as close to the Special Town Meeting as possible without 500 voters present. A committee member was stationed in each corner and given a distinct handset key to click. We tested the USB receiver and the remote receiver separately. The distance from the stage of the gymnasium/cafeteria to the far wall is approximately 300 feet.

The handsets at the front corners of the gymnasium (closest to the voting computer) worked flawlessly under all circumstances. Using the USB receiver, the handsets at the far end of the cafeteria had delayed responses or required multiple votes if unobstructed. If obstructed by furniture or people, the handsets did not register with the voting computer.

Using the remote receiver on a tripod in the center of the gymnasium, the handsets at all four corners of the gymnasium/cafeteria received immediate and correct responses, even when obstructed by three closely spaced committee members or a vertically stowed cafeteria table.

We also tested various alignments of the remote receiver and found that the alignment was not a factor.

The remote antenna was mounted at the top of a metal tripod. There was some discussion about whether the tripod interfered with the remote antenna. There was no direct evidence of this, but we agreed that mounting it on a wood or plastic pole several feet above the tripod would reduce the chance of interference, as would the use of a fiberglass tripod.

Practice in Other Towns

The moderator polled the Massachusetts Moderators Association chat line (the "Gavel Line") to inquire whether other towns using the Turning system regularly compare the number of votes cast to the number of voters checked in for the meeting. Two moderators responded. One compares the number of votes counted to those checked-in; as in Manchester, she has had a third button programmed to record abstentions. She has used electronic voting at only one very large meeting (2,500 voters in attendance) and reports that "the tally of pro, con, and abstain was within single digits of the total check-in vote count consistently…. I was surprised at the number who abstained." She plans to continue comparing the vote count to the number checked in. The other does not compare votes cast to the number checked in and has not experienced any problems similar to ours. She noted that her town has never needed two rooms.

Probable Cause

The committee concluded that the system behavior at the Special Town Meeting was consistent with the USB receiver at the voting computer active on channel 72 and the remote receiver active on some other channel. This conclusion is also consistent with the behavior of the system when a second receiver was activated.

It must be noted, however, that this conclusion is inconsistent with the fact that both the USB receiver used at Town Meeting and the remote receiver were set to channel 72 when the committee received the equipment. Between the Town Meeting and the delivery of the equipment to the committee, the Town Administrator and the Town Clerk checked the system. They may have changed the channel on the remote receiver when they found it set incorrectly.

Conclusions

The committee concludes:

1. With a high degree of confidence, though not certainty, the cause of the system failure at the Special Town Meeting was an unanticipated system behavior when configured with two receivers. Specifically, when the second receiver was connected, it changed its channel from 72 to some other channel to avoid conflict with the first receiver. As a result, the system used the lower powered, badly located USB receiver at the voting computer rather than the higher powered, centrally located remote receiver.
2. If properly installed and rigorously tested during town meeting setup, the Turning Technologies equipment is capable of accurately and reliably recording votes for future Town Meetings.

Setup and Test Recommendations

The committee offers the following recommendations for subsequent Town Meetings

1. Setup the system using **only** the remote receiver and locate the receiver in the approximate middle of the room. The remote receiver should be at least 8 feet off the floor and at least two feet from any metal in its support.
2. Verify that the computer is set to channel 72 and that it sees the remote receiver.
3. Just prior to the meeting, verify that the system is operating correctly by stationing tellers at the four corners of the room. Each teller should be given a distinct number to press other than 1, 2, and 3. Using the Communications/Test dialog in the Turning Point system, have each of the four tellers vote and check to see that their votes are being recorded correctly and that the handset responds with a green LED when the button is pressed.
4. The Moderator should continue the practice of asking a test question or two before voting begins. This gives him/her confidence that a predetermined response is received. It also helps acquaint the voters with voting with clickers.
5. Between votes, the person running the vote computer should bring up the Communications/Test dialog on the Turning Point system, which will cause it to respond to handset clicks without an actual vote. The tellers should periodically test handset reception in each of the four corners of the seating area. If any of these handsets demonstrate poor reception such as a delayed response or failure to register a green LED, the moderator should consider discontinuing use of the electronic voting system.