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Earthquake Early Warning System

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Earthquake Early-Warning System

Abstract:

In the event of an earthquake, a warning system can significantly aid those in affected areas as well as emergency response personnel. A few-seconds warning can allow a person to seek protection from falling objects, exit enclosed spaces (such as elevators), or move away from windows. Additionally, automatic systems could engage to send a message regarding an individual's location, shut down gas pipelines, or prevent a subway train from departing a station. Current earthquake warning systems collect information from seismographic measuring stations to both monitor current tectonic conditions and alert personnel when those conditions become unstable. Unfortunately, cost and other considerations limit the use and expansion of dedicated seismographic monitoring stations. However, an earthquake early-warning system that collects and aggregates motion data from many individual mobile devices is both scalable and implementable in a more-rapid fashion and at significantly reduced cost. Additionally, an earthquake early-warning system built on information collected from mobile devices could alert those very same mobile devices and other nearby devices or systems in the event of a detected earthquake.

Keywords:

Smart device, WiFi, Bluetooth, Internet-of-Things, voice-activated, assistant, electronic assistant, smart home, automation, motion, vibration, shaking, earthquake, server, data collection, data aggregation, emergency, signal, warning, seismograph, seismography.

Background:

As the number of mobile devices expands, data collected via mobile device can improve the lives of not only the mobile device users themselves but also those near those mobile devices.

For example, mobile devices feature a number of different sensors that can measure vibration, orientation, temperature, humidity, barometric pressure, and many other attributes without the need of installation of permanent sensing technology (*e.g.*, a dedicated seismograph for measuring vibration), which can be costly, inconvenient, or even impractical in certain circumstances. For example, advances in mobile device technology have resulted in advanced sensing capabilities that can detect very slight movements of the mobile devices. Although most movement is unique to each individual mobile device, large-scale movements can be sensed by many different mobile devices in the area of the large-scale movement. Data aggregated from the many different mobile devices in the area of the large-scale movement can help detect, monitor, and provide notice of the large-scale movements, such as earthquakes. The notice can be distributed to the mobile devices themselves, other devices or systems in the area, or other devices or systems in areas adjacent or near the large-scale movements.

Description:

In the event of an earthquake, a warning system can significantly aid those in affected areas as well as emergency response personnel. A few-seconds warning can allow a person to seek protection from falling objects, exit enclosed spaces (such as elevators), or move away from windows. Additionally, automatic systems could engage to send a message regarding an individual’s location, shut down gas pipelines, or prevent a subway train from departing a station. Current earthquake warning systems collect information from seismographic measuring stations to both monitor current tectonic conditions and alert personnel when those conditions become unstable. Unfortunately, cost and other considerations limit the use and expansion of dedicated seismographic monitoring stations. However, an earthquake early-warning system that collects and aggregates motion data from many individual mobile devices is both scalable and implementable in a more-rapid fashion and at significantly reduced cost. Additionally, an earthquake early-warning system built on information collected from mobile devices could alert those very same mobile devices and other nearby devices or systems in the event of a detected earthquake. The earthquake early-warning system comprises two general components: mobile devices from which data is collected and a server component at which data from the mobile devices is aggregated and analyzed.

First, data is collected from any number of mobile devices. For example, consider the urban scene illustrated in Figure 1. Here, several different mobile devices are illustrated. A woman running down the street near a building wears a smart watch or other fitness monitor. A man standing near the corner of the building has a mobile phone inside his jacket pocket. A woman near another corner of the building actively views content on her mobile device. Additionally, a tablet computing device lies on a desk inside the building and is plugged into a wall outlet. Each of these mobile devices may be equipped with any number of different sensors that can measure vibration, orientation, temperature, sound, light, humidity, barometric pressure, geographic location, electric or magnetic fields, elevation, and many other attributes. Such sensors include gyroscopes, accelerometers, cameras, magnetometers, barometers, microphones, or global positioning systems among many others. Some sensors or systems may serve multiple purposes. For example, a camera image stabilization sensor normally configured to compensate for motion of a mobile computing device when taking pictures could also detect subtle movement associated with other large-scale motion, such as that generated by an earthquake.

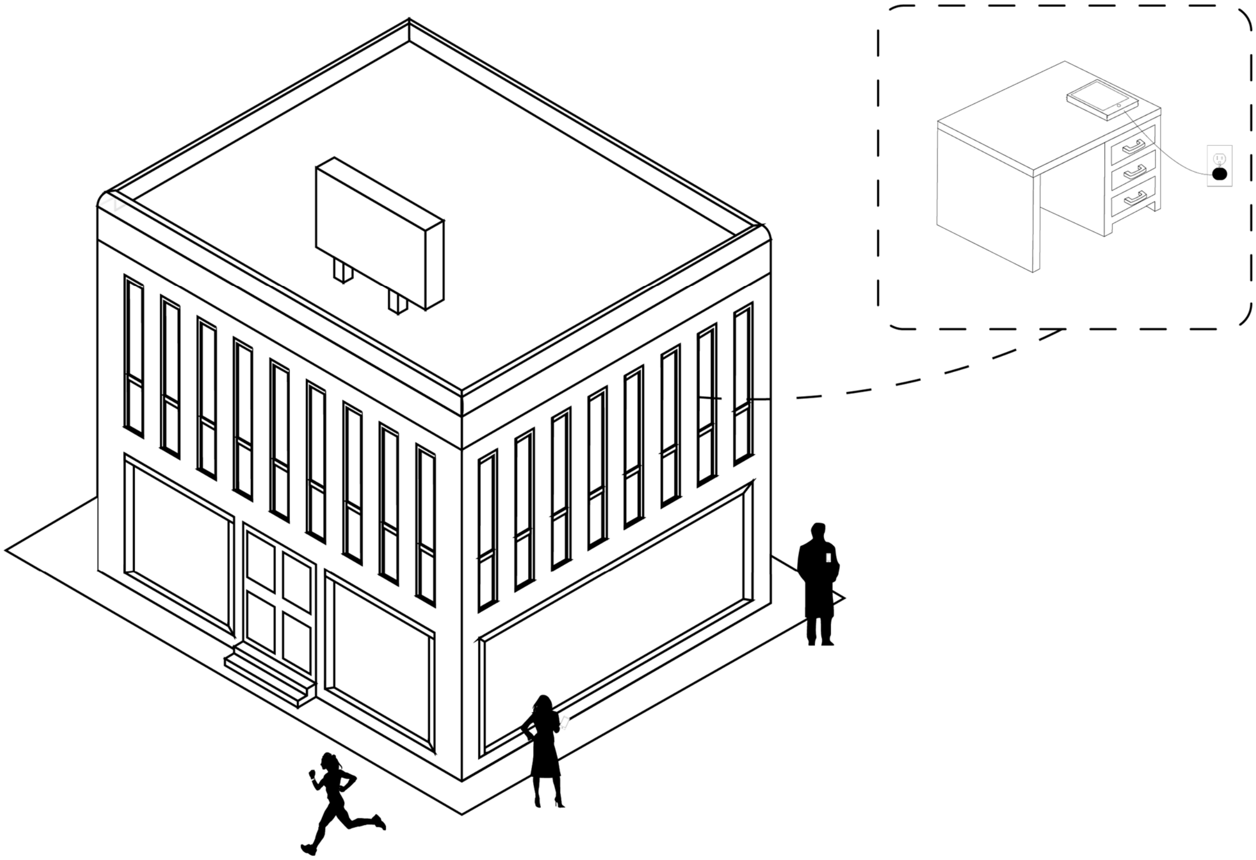

Figure 1

Here, much of the movement of any of these mobile devices may be indicative of ordinary activity. For example, the motion of the mobile devices of the woman running or the woman viewing content on her phone are common in everyday life. So is the gentle swaying of the mobile device of the man standing on the corner. A computing system of each device could initially evaluate the data collected by an accelerometer, gyroscope, or other sensor and determine with a high probability that the movement is "normal" based on historical patterns of an individual user or general user patterns of individual mobile devices.

Mobile computing devices include batteries or other finite power supplies. Many mobile devices may operate in a low-power mode yet still have the capacity to process sensor data via various sensor hubs or other dedicated components, which can be very advantageous when collecting data from mobile devices without overburdening power supplies.

The tablet computing device resting on the desk in the building allows for collection of somewhat different data. A computing system of the tablet computing device can determine that the tablet computing device is at rest. The computing system may also recognize normal movements common to a tablet computing device, such as a user lifting the tablet computing device from the desk or sliding it sideways on the desk. The computing system could also combine data from other sensors, such as a light sensor or camera, to determine motion is normal, such as recognizing a common face or removing a power-cord connection prior to a picking-up movement. Data from any numbers of sensors could be aggregated to evaluate whether a motion is normal or potentially abnormal.

The computing system of the tablet computing device can also recognize very subtle motions not indicative of normal, everyday motion. For example, earthquakes involve very subtle motion unlike the lifting up or sliding motions noted above. A computing system of the tablet computing device could initially identify motion sensed by an accelerometer or gyroscope as "abnormal" and forward the measured data on to a server computing system for further analysis. Alternatively, the tablet computing device (or any of the mobile devices noted above) could forward all data collected to the server computing system for analysis.

Compared to the other mobile devices, the tablet computing device also features another advantageous feature in detecting motion as a component of an earthquake early-warning system: a constant power supply. In mobile devices, finite power resources often limit data collection, data analysis, and data transmission activities because mobile devices enter power-saving modes, which often involve putting various components to sleep. In an early-warning system for earthquakes, seconds count. The time required to wake a sensor, sense a condition, wake a processor, analyze a condition, wake a transmitter, and transmit data to a server system for further analysis could render the entire earthquake-detection system too sluggish and slow to be practically useful. Here, the tablet computing device can keep its sensors, processors, and transmitters in an active state because the constant power supply minimizes the need to place any components in a low-power or sleep mode.

As the Internet-of-Things expands, other less-mobile or non-mobile smart devices with reliable power connections continue to proliferate and could contribute sensed data to an earthquake early-warning system. Smart devices include things like thermostats, home assistants, ovens, refrigerators, cameras, lights, switches, security systems, monitors, appliances, or home theater components, many of which include a variety of sensors and reliable power connections. A smart device can be directly connected to the Internet or indirectly connected to the Internet via a communication hub. The smart devices can be accessed and manipulated using a web browser, an application on a mobile device, a local remote, or programing system (*e.g.*, voice commands, home automation systems). Such smart devices are already designed to connect and interact with one another. Any number of such smart devices could contribute valuable sensor information data to an earthquake early-warning system.

As noted above, an individual mobile device can sense and detect valuable data. However, it is difficult to detect an earthquake with a high degree of certainty based on data sensed at a single mobile device. A false positive earthquake indication could inadvertently trigger a warning system, which could have very significant consequences. Here, a unique advantage of the earthquake early-detection system is the aggregation of sensed data from many devices and the analysis of that data by a server system, which can feature greater computing power and other resources not available to the individual mobile devices. Consider the representation of Sydney, Australia, illustrated in Figure 2 below, showing the Sydney Opera House, the city skyline, and a subway car.

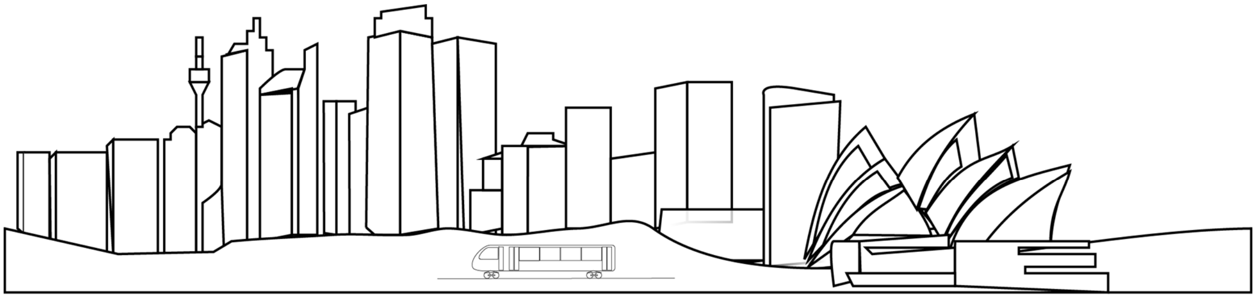

Figure 2

The earthquake early-warning system can receive sensed data from many mobile devices at a server system, such as mobile devices on the subway, at the opera house, or in the buildings. The server system analyzes the received data looking for trends or patterns among the mobile devices and compares those trends or patterns to trends or patterns of other mobile devices. Many mobile devices periodically check-in with a central server system to maintain connectivity. Thus, the server system has a unique advantage in that it can “know” how many mobile devices are within a certain geographic region when evaluating sensed data from the mobile devices and determine how many of the known mobile devices sensed any particular condition.

For example, the server system could receive sensed motion or vibration data from mobile devices of travelers on the subway system. In isolation, the movement of mobile devices in a subway car in motion could indicate a large-scale event, such as an earthquake. Likewise, the vibration felt by mobile devices in the opera house could also indicate a large-scale event. The server system can compare the motions of the mobile devices in the subway to those at the opera house and determine whether or not the motion is indicative of some common event. The server system can also compare the mobile device sensor data from mobile devices in nearby buildings or buildings between the subway car and the opera house to further evaluate the data. Here, the server system could determine whether or not a sensed motion is common among the mobile devices and whether those mobile devices sensing the common motion comprise a threshold number of the total number of mobile devices in a geographic area when determining whether or not the sensed motion indicates a large-scale event, like an earthquake.

For example, consider the maps of a geographic region shown in Figures 3-5 illustrating the operation of the earthquake early-warning system. In Figure 3, several individual mobile devices identify abnormal movement and communicate this information to the server system. The concentric rings of Figures 3-5 represent the propagation of the earthquake from the central epicenter or origin.

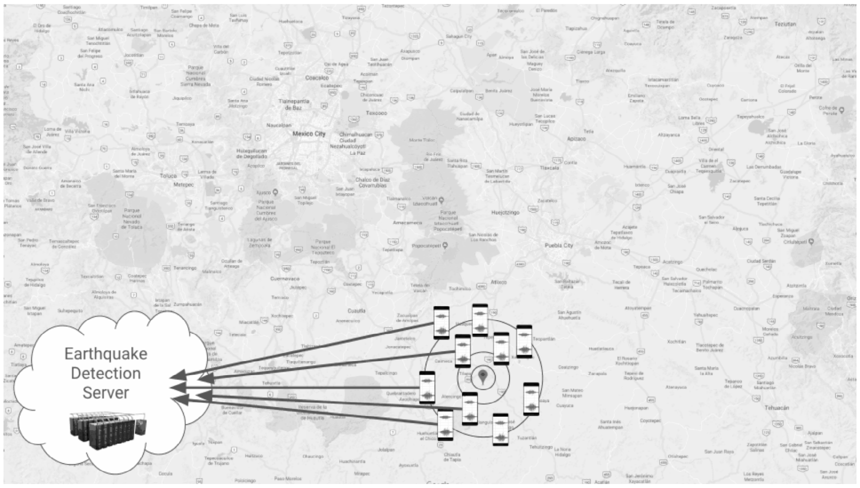

Figure 3

In Figure 4, the server system conducts further analysis and confirms the abnormal movement as an earthquake. The server system, with larger resources and computing power than an individual mobile device, can confirm or correlate the abnormal movement by querying local seismographic measuring stations or other devices. The server system could also identify other large-scale events or distinguish such event from an earthquake, such as a building demolition, a bomb detonation, or a mining operation. Based on the determined large-scale event, the server system prepares an emergency alert or other warning to contributing or connected mobile devices, emergency systems, and other entities in the geographic region of the earthquake or large-scale event and those areas adjacent the geographic region.

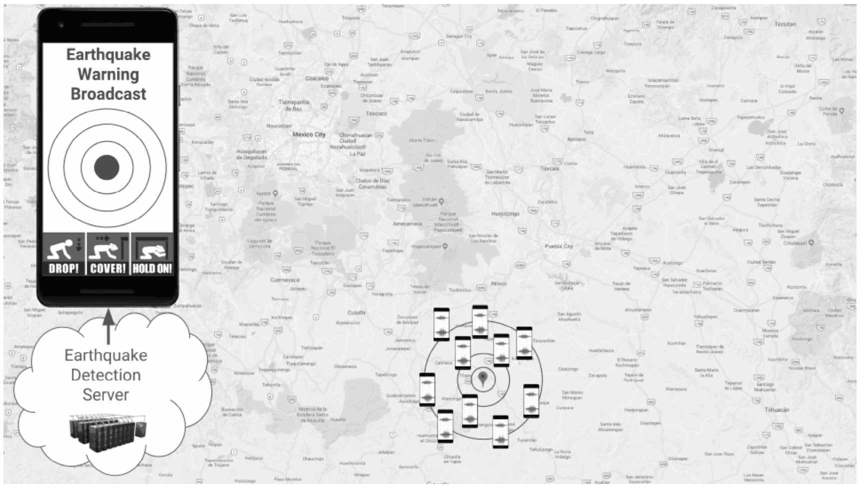

Figure 4

Figure 4 also illustrates an important safety or false-alarm prevention feature of the earthquake early-warning system. A false alarm or false-positive identification of an earthquake or other large-scale event could cause panic, unnecessary travel or movement, fear, or activation of emergency systems that disrupt normal operations, such as the utility rerouting systems noted above. As shown above in Figure 4, the server system makes the ultimate determination as to whether or not an earthquake is occurring and whether an emergency response should be initiated. As the number of mobile devices connected to the early-warning system increases, the ability of a single or even a number of mobile devices to inadvertently or even intentionally spoof or deceive the system decreases. The server system may also query other information and data sources not available to the individual mobile devices to confirm the earthquake. For example, a local building demolition could generate an earthquake-like movement at an epicenter-like location in many nearby mobile devices. The server system could factor such events into its analysis protocols.

In Figure 5, the warning or emergency alert spreads to those areas adjacent to or not yet impacted by the earthquake or other large-scale event. This warning or alert could initiate a variety of messages, procedures, activities, or responses. For example, a text message, alert, or other emergency notification could be sent to individual mobile devices, emergency response personnel, news media, cell phone carriers, or government agencies. This alert could arrive before infrastructure begins to fail or incurs damage and provide individuals, groups, or entities time to seek shelter or better prepare for disruption. For example, a medical facility could receive an alert and medical procedures could be paused or delayed or medical care professionals could have a short time in which to stabilize a surgery patient. Elevators could be programmed to stop at the next available floor and allow patrons to exit and seek the stairwells. Utilities could be programmed to automatically close natural gas lines, cut electrical power to high-risk areas, or prepare to reroute utilities to high priority areas, such as schools or medical-care facilities. Factories, airports, subway systems, or other entities could receive the warning and initiate emergency protocols.

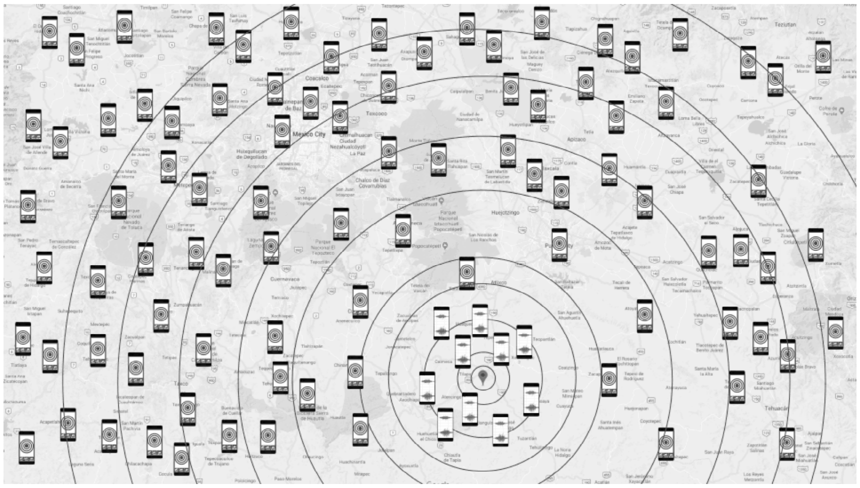

Figure 5

The server system could also alert individual mobile devices to communicate their geographic locations whether or not those mobile devices provided sensed data to the server system, which could aid emergency response personnel. The server system could also instruct mobile device operating systems to enter a low-power mode in which other systems power down so that geographic location systems or beaconing modes, including wireless network protocols providing “heartbeat” signals, may remain active for as long as possible.

As they continue to proliferate, mobile devices present opportunities to improve data collection and aggregation in an earthquake early-warning system. Such an earthquake early-warning system, built on information collected from mobile devices, could alert those very same mobile devices and other nearby devices or systems in the event of a detected earthquake.