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PROTECTION OF CABLES AND OTHER ELEMENTS  
OF OUTSIDE PLANT

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## **Monitoring systems for outside plant facilities**

Recommendation ITU-T L.81





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## Monitoring systems for outside plant facilities

### Summary

Natural disasters such as those caused by strong wind, flood, landslide, and earthquake happen more frequently than ever and their damage is increasing. Human-caused disasters such as those caused by fire, explosion, and collapse also happen on a large scale. Outside plant facilities including telecommunication buildings are exposed to these disasters and may be affected adversely, which implies that preventive measures are needed. Recommendation ITU-T L.81 deals with monitoring systems to mitigate damage and to secure outside plant facilities against disasters.

### History

Edition	Recommendation	Approval	Study Group
1.0	ITU-T L.81	2009-11-13	15

### Keywords

Disaster, emergency management, monitoring system, structural health monitoring (SHM), wireless sensor network (WSN).

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# Recommendation ITU-T L.81

## Monitoring systems for outside plant facilities

### 1 Scope

This Recommendation:

- describes typical emergency management for outside plant facilities;
- describes monitoring systems for outside plant facilities using wireless or wired network;
- provides an overview of disaster monitoring systems for outside plant facilities;
- provides design considerations for disaster monitoring systems for outside plant facilities.

It should be noted that fire disasters are not considered in this Recommendation because disaster management concerning fire is described in [ITU-T L.20], [ITU-T L.21] and [ITU-T L.22].

### 2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

- [ITU-T L.11] Recommendation ITU-T L.11 (1988), *Joint use of tunnels by pipelines and telecommunication cables, and the standardization of underground duct plans.*
- [ITU-T L.20] Recommendation ITU-T L.20 (1996), *Creation of a fire security code for telecommunication facilities.*
- [ITU-T L.21] Recommendation ITU-T L.21 (1996), *Fire detection and alarm systems, detector and sounder devices.*
- [ITU-T L.22] Recommendation ITU-T L.22 (1996), *Fire protection.*
- [ITU-T Y.1271] Recommendation ITU-T Y.1271 (2004), *Framework(s) on network requirements and capabilities to support emergency telecommunications over evolving circuit-switched and packet-switched networks.*

### 3 Definitions

#### 3.1 Terms defined elsewhere

This Recommendation does not use any terms defined elsewhere.

#### 3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

**3.2.1 disaster:** Disasters are characterized by the scope of an emergency. An emergency becomes a disaster when it exceeds the capability of the local resources to manage it. Disasters often result in great damage, loss, or destruction.

**3.2.2 early warning:** The provision of timely and effective information, through identified institutions, that allows individuals exposed to a hazard to take action to avoid or reduce their risk and prepare for effective response.

**3.2.3 emergency:** An emergency is a sudden, urgent, usually unexpected occurrence or event requiring immediate action.

**3.2.4 structural health monitoring (SHM):** The process of continuously monitoring the status of a structure to detect damage.

**3.2.5 wireless sensor network (WSN):** A wireless network consists of spatially distributed autonomous devices using sensors to cooperatively monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants, at different locations.

## **4 Abbreviations and acronyms**

This Recommendation uses the following abbreviations:

GSM Global System for Mobile Communications

LAN Local Area Network

SHM Structural Health Monitoring

WAN Wide Area Network

WSN Wireless Sensor Network

## **5 Conventions**

None.

## **6 Disasters and emergency management for outside plant facilities**

### **6.1 Typical disasters**

Disasters are categorized into natural disasters and human-caused disasters. Natural disasters include those unplanned events that occur as a result of natural processes such as strong wind, flood, severe storm, landslide, earthquake, and tsunami. Human-caused disasters are those unplanned events or accidents that result from human activity or human developments, including urban fire, utility failures, collapse, explosion, and environmental disasters.

### **6.2 Emergency management**

Emergency management activities can be grouped into four phases as follows:

- Mitigation (Prevention): Activities that actually eliminate or reduce the probability of a disaster.
- Preparedness: Activities prior to an emergency that are used to support the prevention of, mitigation of, response to, and recovery from emergencies. In this phase, plans are developed to save lives and minimize disaster damage (for example, installing early warning systems).
- Response: Activities following an emergency or disaster. These activities are designed to provide emergency assistance for victims, to stabilize the situation and to reduce the probability of secondary damage.
- Recovery: Activities necessary to return all systems to normal or better (for example, rebuilding destroyed property, or the repair of other essential infrastructure).



### 6.3 Emergency management programs for outside plant facilities

To make outside plant facilities more reliable and stable against disasters, it is recommended that emergency management programs be provided. Typical examples of emergency management programs are listed in Table 1.

**Table 1 – Typical examples of emergency management programs for outside plant facilities**

Disasters	Potential consequences	Possible preventive measures <sup>a)</sup>	Phase <sup>b)</sup>
Strong wind	<ul style="list-style-type: none"> <li>• Overturning of telecommunication poles or towers.</li> <li>• Disconnection of cables.</li> </ul>	• Observe design criteria for protection against strong wind.	M
		• Installation of supports (i.e., struts or guy line).	P
Flood	<ul style="list-style-type: none"> <li>• Immersion of telephone office and cable tunnels.</li> </ul>	• Restrict installation in potential flood zones.	M
		• Installation of waterproof doors, water pump or monitoring system.	P
Landslide	<ul style="list-style-type: none"> <li>• Duct bursts and disconnection of cables.</li> <li>• Damage to outside plant facilities.</li> <li>• Failures of earth retaining structures.</li> </ul>	• Restrict installation in potential landslide zones.	M
		<ul style="list-style-type: none"> <li>• Periodic inspection.</li> <li>• Monitoring by measurement.</li> <li>• Installation of monitoring system.</li> </ul>	P
Earthquake	<ul style="list-style-type: none"> <li>• Destruction of telephone office including outside plant facilities.</li> <li>• Breakdown of telecommunication equipments including Internet server.</li> <li>• Duct bursts and disconnection of cables.</li> <li>• Secondary damages such as fire, shutting off electricity.</li> </ul>	<ul style="list-style-type: none"> <li>• Restrict installation in active earthquake fault.</li> <li>• Legislation that requires earthquake-resistant building codes.</li> </ul>	M
		<ul style="list-style-type: none"> <li>• Installation of vibration controlling or mitigating system.</li> <li>• Installation of SHM.</li> </ul>	P
Lightning	<ul style="list-style-type: none"> <li>• Breakdown or failure of telecommunication equipments.</li> </ul>	• Protection of outside plant against lightning-induced surges.	P
Collapse	<ul style="list-style-type: none"> <li>• Destruction of telephone office and cable tunnels.</li> <li>• Duct bursts and disconnection of cables.</li> </ul>	<ul style="list-style-type: none"> <li>• Observe building design criteria.</li> <li>• Restrict new construction adjacent to existing outside plant facilities.</li> </ul>	M
		<ul style="list-style-type: none"> <li>• Periodic inspection.</li> <li>• Monitoring by measurement.</li> <li>• Installation of SHM.</li> </ul>	P
Excavation	<ul style="list-style-type: none"> <li>• Disconnection of cables.</li> </ul>	• Restrict new construction adjacent to existing underground cables.	M
Terror	<ul style="list-style-type: none"> <li>• Fire.</li> <li>• Explosion.</li> <li>• Duct burst.</li> </ul>	<ul style="list-style-type: none"> <li>• Control entry personnel.</li> <li>• Installation of monitoring system for security.</li> </ul>	P

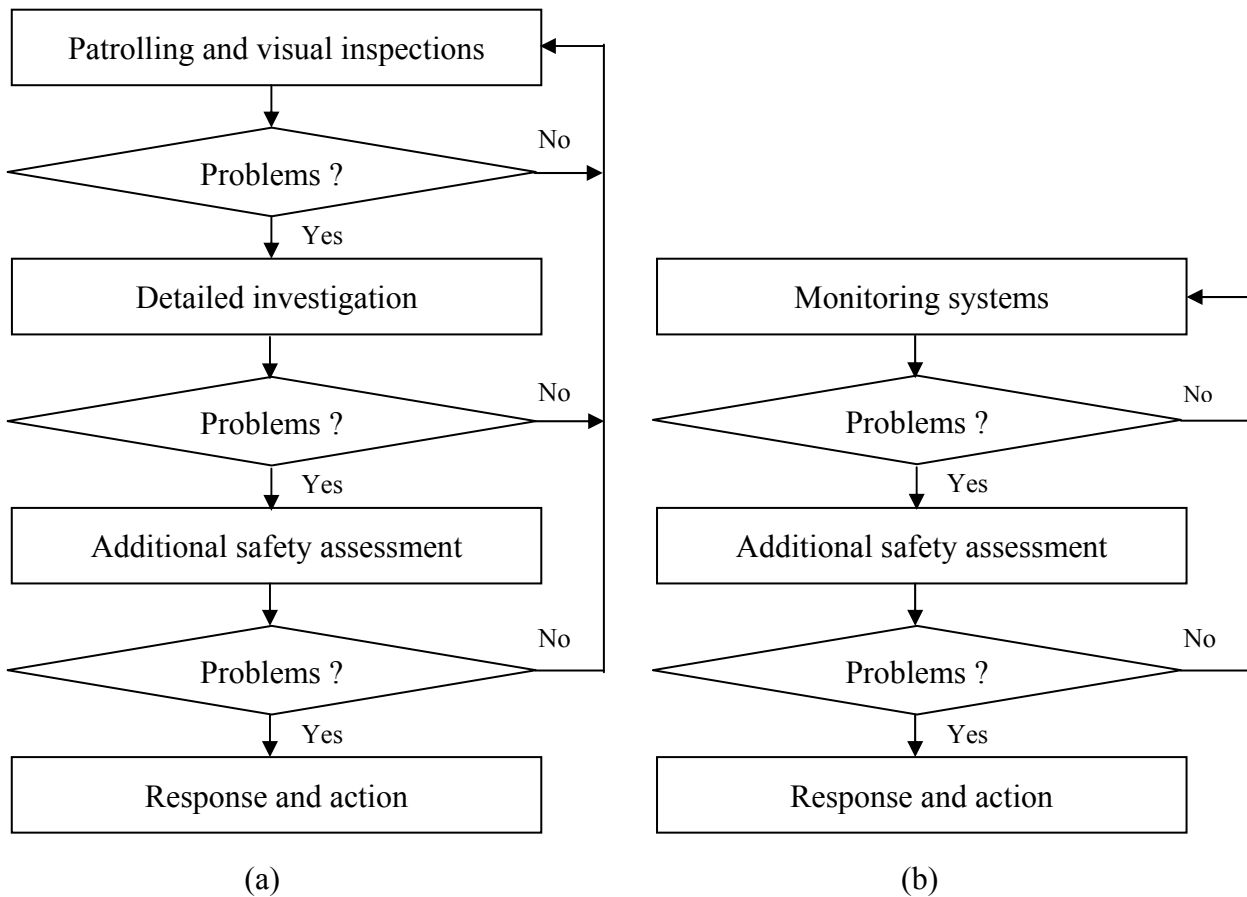
<sup>a)</sup> The above list of preventive measures is not exhaustive.

<sup>b)</sup> M: Mitigation, P: Preparedness. Other emergency management phases such as response and recovery are not considered.

## 6.4 Monitoring flow diagram

Manually operated monitoring procedures for outside plant facilities are described in Figure 1-a. Patrolling and visual inspections are carried out by facility member staffs, and a detailed investigation follows when any defects are detected. If critical factors which may cause an accident are detected at this stage, additional safety assessment is carried out.

As shown in Figure 1-b, monitoring systems by sensor network omit some of these stages, and thus make it labour-saving and efficient to maintain the outside plant facilities. In addition, monitoring systems allow facility member staffs to quickly find critical data that ensure outside plant facilities operate 24 hours a day.



**Figure 1 – Monitoring flow diagram: (a) manually operated monitoring method; (b) monitoring systems**

## 7 Monitoring system for outside plant facilities

### 7.1 Objectives

The objective of the monitoring system is to detect defects in an early stage, and to deliver warning messages to disaster managers rapidly when the defects are not tolerant. These activities can be performed by persons, but it may cost much time and effort when the structures or facilities to be monitored are big and spatially scattered over a wide area. In addition, small defects that may cause great disasters are apt to be overlooked by only manual inspection. Therefore, it is required to establish more sophisticated countermeasures such as an early-warning monitoring system.

## 7.2 General requirements

It is recommended that the monitoring system for outside plant facilities be:

- designed to carry out proper response action rapidly in the emergency;
- implemented by reliable, stable and proven technology not to give a false alarm;
- operated in real-time or near real-time manner;
- designed to provide alerting without delay for facility staff members;
- tested and verified before application and regularly checked.

## 7.3 Design considerations

### 7.3.1 Wired/wireless systems

Monitoring system for outside plant facilities is to sense the physical or environmental conditions by sensors, and then to notify facility staff members through the way of wired or wireless system. Comparisons between wired and wireless systems are presented in Table 2. Wired system is recommended when a higher reliability is required.

**Table 2 – Comparisons between wired and wireless system**

Type	Advantages	Disadvantages
Wired system	<ul style="list-style-type: none"> <li>– stable and proven technology.</li> </ul>	<ul style="list-style-type: none"> <li>– involves many long lengths of cable to cover the large spatial distances;</li> <li>– expensive to install;</li> <li>– cables can fail due to exposure to the environment or potential damage during extreme events;</li> <li>– long cables result in sensor signal degradation.</li> </ul>
Wireless system	<ul style="list-style-type: none"> <li>– no cables are required for data transfer;</li> <li>– system setup and maintenance cost can be remarkably reduced;</li> <li>– in the case of partial system failure, the rest of the system is capable of performing its task independently.</li> </ul>	<ul style="list-style-type: none"> <li>– power and communication bandwidth available on the node are very limited;</li> <li>– each node has restricted battery life.</li> </ul>

#### 7.3.1.1 Wired system

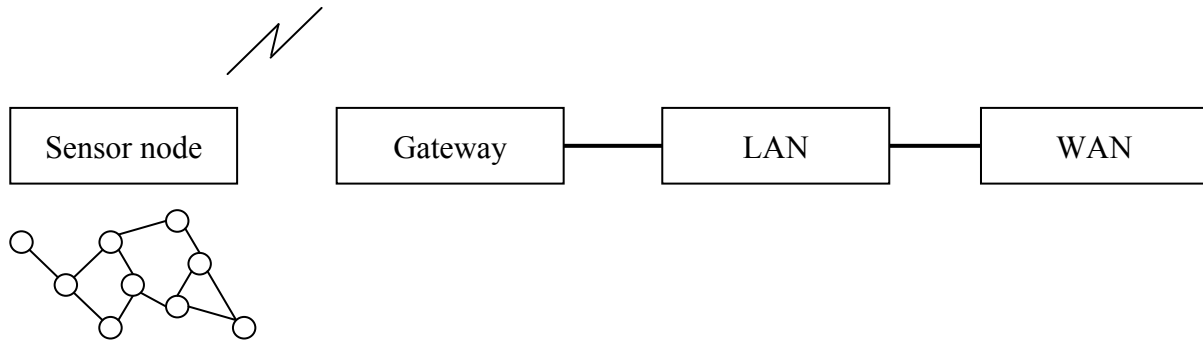
In this system, the sensor is generally hard-wired to a data acquisition system which is linked to the base station by a cable. An example of network configuration using Ethernet is shown in Figure 2.



**Figure 2 – Example of network configuration (wired system)**

### 7.3.1.2 Wireless system

In this system, the sensed data are sent to a gateway (Base Station) via radio. Radio frequencies, power and protocols vary greatly among different systems. Some of the wireless systems available are GSM, WiFi, Bluetooth, and ZigBee, etc. The type of wireless systems to be used depends upon factors such as frequency, data rate, range, and monitoring characteristics, etc. Typical network configuration is shown in Figure 3. A sensor node is a basic unit which is composed of sensing, processing, communication, and a power unit. Communication between gateway and LAN will be via wired or wireless.



**Figure 3 – Typical network configuration (wireless system)**

### 7.3.2 Sensors

Parameters to be sensed in the monitoring system are deformation, angle, vibration, and temperature, etc. Typical sensors and their applications are presented in Table 3.

**Table 3 – Typical sensors for outside plant facilities**

Parameters	Sensors	Descriptions	Applications
Deformation	<ul style="list-style-type: none"> <li>Crack gage, Convergence gage, Strain gage</li> </ul>	<ul style="list-style-type: none"> <li>To monitor changing distances between two points</li> </ul>	<ul style="list-style-type: none"> <li>Monitoring crack width of building, cable tunnel, and manhole</li> </ul>
	<ul style="list-style-type: none"> <li>Fibre-optic sensor</li> </ul>	<ul style="list-style-type: none"> <li>To monitor changing distances between two points</li> <li>Optical fibre Bragg grating (FBG)</li> </ul>	<ul style="list-style-type: none"> <li>Monitoring deformation of civil infrastructures such as buildings, slopes, tunnels, underground pipes, etc.</li> </ul>
	<ul style="list-style-type: none"> <li>Probe extensometer</li> </ul>	<ul style="list-style-type: none"> <li>To monitor the changing distance between two or more points along a common axis</li> </ul>	<ul style="list-style-type: none"> <li>Monitoring ground movement and settlement</li> </ul>
	<ul style="list-style-type: none"> <li>Inclinometer</li> </ul>	<ul style="list-style-type: none"> <li>To monitor the changing vertical deformations along a common axis</li> </ul>	<ul style="list-style-type: none"> <li>Landslide detection</li> </ul>
Angle	<ul style="list-style-type: none"> <li>Tiltmeter</li> </ul>	<ul style="list-style-type: none"> <li>To monitor the change in inclination (rotation) of points</li> </ul>	<ul style="list-style-type: none"> <li>Monitoring earth retaining wall</li> <li>Detecting inclination of telecommunication pole or tower</li> </ul>

**Table 3 – Typical sensors for outside plant facilities**

<b>Parameters</b>	<b>Sensors</b>	<b>Descriptions</b>	<b>Applications</b>
Vibration	<ul style="list-style-type: none"><li>• Accelerometers</li></ul>	<ul style="list-style-type: none"><li>• To monitor dynamic response, either harmonic (e.g., vibration) or transient (e.g., earthquake)</li></ul>	<ul style="list-style-type: none"><li>• Monitoring office vibration by traffic or earthquake</li></ul>
Temperature	<ul style="list-style-type: none"><li>• Thermometer</li></ul>	<ul style="list-style-type: none"><li>• To monitor temperature</li></ul>	<ul style="list-style-type: none"><li>• Monitoring temperature in server rack</li></ul>
Water level	<ul style="list-style-type: none"><li>• Piezometer</li></ul>	<ul style="list-style-type: none"><li>• To monitor water level and/or water pressure</li></ul>	<ul style="list-style-type: none"><li>• Flood detection in telephone office or cable tunnel</li></ul>
Security	<ul style="list-style-type: none"><li>• Motion detector</li></ul>	<ul style="list-style-type: none"><li>• To detect motion</li></ul>	<ul style="list-style-type: none"><li>• Detecting intruder to secure restricted area</li></ul>

### **7.3.3 Communication model**

There are two types of communication models: a pull model and a push model. A pull model requests sensed data periodically in a certain time interval. A push model proactively transmits sensed data only when an event exceeds a predetermined level. It is recommended that a push model be used for a disaster monitoring system.

## Appendix I

### Korean experience

(This appendix does not form an integral part of this Recommendation)

#### I.1 Monitoring system for outside plant facilities using WSN

Design considerations on the deployment of monitoring system are presented in Table I.1.

**Table I.1 – Design considerations**

Items	Descriptions
Network topology	– In WSN, there are star and tree (mesh) network topologies. Network topology affects network characteristics such as latency, robustness, and capacity.
Power supply	– WSN can be easily deployed to the sites even where the infrastructures such as communication and electricity are not installed. But the battery which provides sensor node with energy will be depleted, and thus power unit is one of the most important components to be considered.
Threshold	– Monitoring system performs early warning. Real-time data gathered by WSN are analysed and alarm is issued if the data exceed prescribed thresholds. – If the threshold is set too low, there will be too many false warnings, so that genuine warnings will not be heeded. On the contrary, if the threshold is set too high, the event which may cause accidents will be missed. – This activation threshold should be set case by case for outside plant facilities.
Sampling rate	– Sampling rate determines how often sampling can take place. A faster sampling rate acquires more data in a given time, and therefore often forms a better representation of the original signal. – For example, earthquake monitoring needs at least 200 Hz data sampling rate, whereas, in the case of temperature or humidity sensing, several samples per day may be enough.

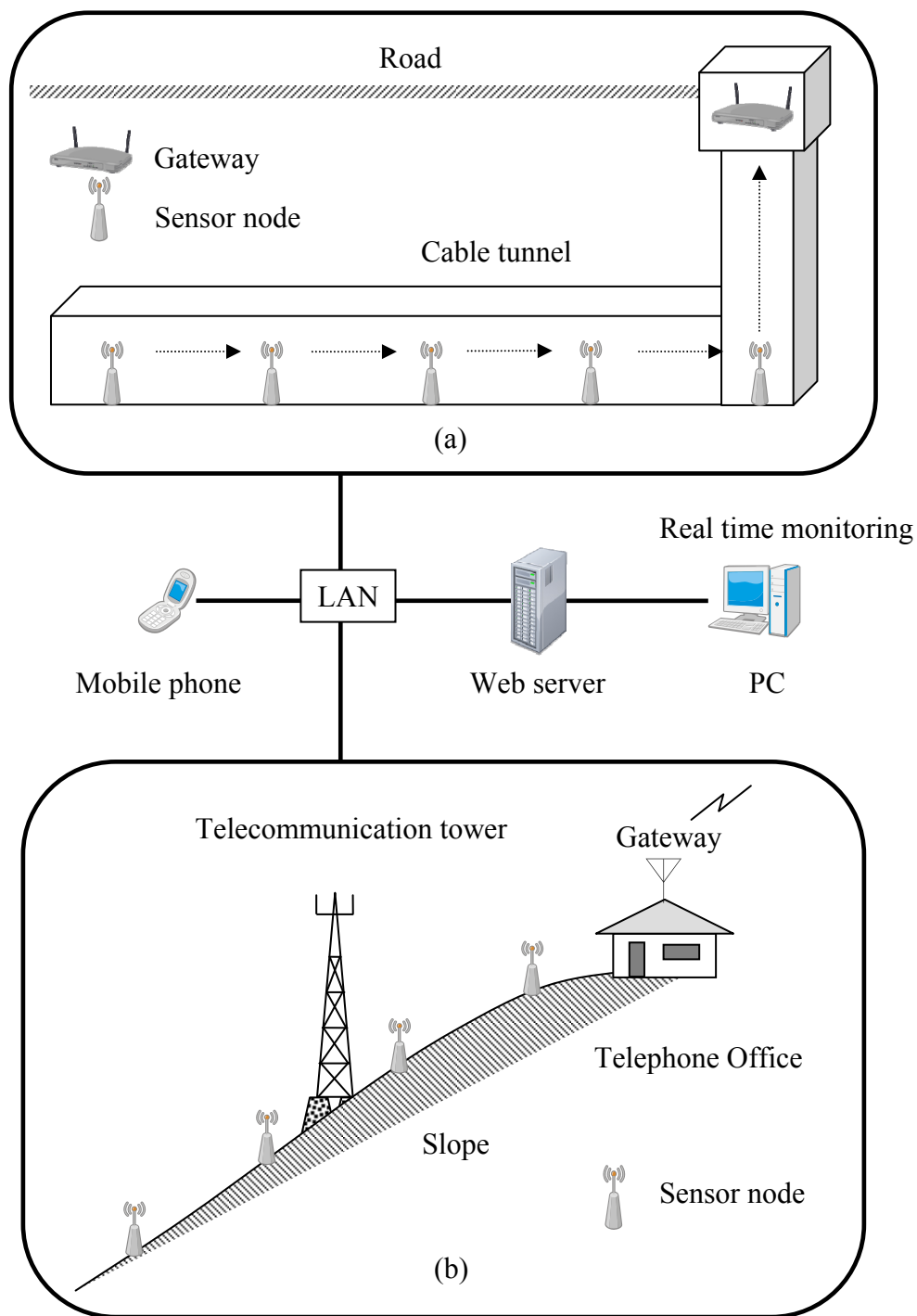
#### I.2 Examples

##### I.2.1 Cable tunnel monitoring

We deployed the cable tunnel monitoring system using WSN. Fire, flood, vibration, temperature and intruder monitoring are performed by sensor nodes, and sensed data are transmitted to the gateway by wireless communication. Data are displayed on a web browser through the Internet, and a facility staff member is notified automatically when an event exceeds the warning level. Schematic drawing of this system is shown in Figure I.1-a.

##### I.2.2 Landslide monitoring

In the case of outside plant facilities on or near steep terrain, landslides are one of the most significant natural hazards. Slope angle and ground vibration are measured every minute, and these data are transmitted to a server computer via radio. Schematic drawing of this system is shown in Figure I.1-b.



**Figure I.1 – Schematic drawing of monitoring systems: (a) cable tunnel monitoring system; (b) landslide monitoring system**

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