RESEARCH ARTICLE OPEN ACCESS

An Overview of Landslide Forecasting Using Wireless Sensor Network and Geographical Information System

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ABSTRACT
Landslides are natural disasters cause losses in many human lives and damage properties every year around the globe. Using of physical and electronic monitoring makes possible in prediction and prevention losses from landslide. Today, the wireless sensor network technology has been developed rapidly for landslide predictions. The primary object of this present paper is to overview the landslide prediction method using wireless sensor networks (WSN) and geographical information systems (GIS). The paper focuses on various landslide conditioning factors, WSN design requirement, and small scale down slope model similar to study area (hazard location). Landslide prediction database to support warning system are also discussed.
***Keywords*:** Landslide, WSN, conditioning factors, GIS

i. INTRODUCTION

Landslides are a geological disaster occurs in a short period due to the variations in environmental actions and causes damages in human lives, properties and agriculture.During the rainy season, unlike divisions of India are affected by the landslide natural hazard every year.The Nilgiri district of Tamil Nadu is one of the severely affected placesin India.In the year 2009,total 1150 landslides were reported during the rainy season[1].Long period monitoring of the landslide hazard zone is needed to preclude from the landslide losses.WSN technology has the capacity of large-scale deployment and real time monitoring of landslide. A landslide detection system with the purpose of a wireless sensor network can find the slightest movements of ground or slope instability due to the several reasons such as dielectric moisture, pore pressure and so on that may occur during a landslide [2].

1.1. Related work

According to the architecture of the landslide monitoring systems, which is composed of two main components, the autonomous WSN and the early warning and information system (EWIS)[3]. The database of landslide monitoring and warning system was described based on WebGIS partly used SQL Server 2008 of Microsoft[4]. Also ArcSDE spatial database used SQL Server 2008 mode of Microsoft[4]. The experimental monitoring for landslide prediction by deploying sensor nodes in scale down model and they also discover the threshold value of landslide triggering due to rainfall,[5],[6]. Three levels of algorithms used for detecting landslide events are explained by [8] and [7]explained need of heterogeneous type of WSN to provide spatially distributed information, algorithms for event detection, classification, localization, evaluation.

II. METHODOLOGY

2.1 Landslide prediction methods:

The sensor nodes are equipped with different sensors (soil pressure sensors, motion sensors, rain gauge, angle sensors) are deployed in the hazardous area and continuously monitor the area, when the events are noticed by the nodes the node elected by a cluster and then clusters head aggregate data from nodes and transmit for the decision to the base station.The base station receives the complete database about the landslide triggering factors, (Four types of algorithms for event detection, information collection, fault tolerance, energy efficient algorithms are taken to support the communication between the monitoring field to the base station). Then the received data are compared with the database and the landslide will be predicted before it occurs.[8][9][10]

2.2 WSN design for landslide

Wireless Sensor Networks (WSNs) are the key emerging technology that has the capability to real-time, continuous data collection, processing, aggregation with minimum maintenance [11]. Wide area monitoring with many numbers of nodes and continuous data collection, processing and aggregation is required for landslide detection. WSNs consist of wireless node, base radio, gateway and design could constrain heterogeneous wireless network with clustering based energy efficient, fault tolerance in network performance. Efficient algorithms for different criteria such that Localization, event detection and data collection algorithms for end nodes, Threshold based data aggregation algorithm for cluster heads and sink nodes and Fault tolerant hierarchical clustering algorithm for whole network are requires and network architecture is shown in fig. 1.

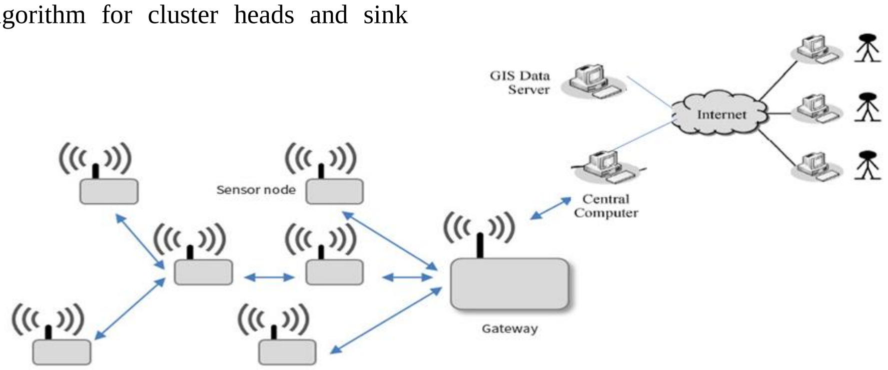

Figure 1: WSN Architecture for landslide monitoring

2.3 Landslide prediction Database:

During the data transmission, the nodes in network consume more power but in landslide monitoring, data collection and aggregation are continuous process which causes reduction in network lifetime. Threshold based alert levels for the whole network has been devised for minimizing energy consumption and also for efficient data handling[12]. Threshold values for different landslide conditioning factors will be identified in two ways, one from geological information and other from sensor nodesthat can be created as landslide prediction database.

Due to rainfall, sensor nodes monitor changes in the side, which are soil moisture, pore water pressure, changes in slope angle.Lab setup, step down model similar to the study area helps to identify the threshold values for alarm levels of rainfall based changing factors. Different sensors (piezometer, accelerometer, tilt sensor, rain gauge) could be installed in the model setup and by pouring artificial rainfall the variations in the slope can be studied and based on that the database will be created in the landslide monitoring center[13]. Based on the different threshold level algorithms could be developed to improve network performance and lifetime.

2.4 GIS:

A geographic information system or geographical information system (**GIS**) is a system designed to capture, store, manipulate, analyze, manage, and present all types of spatial or geographical data[14]–[18]. We use GIS technology to identify the landslide hazard zone in the study area, it can be used to build geological database for the study area.With the help of spatial data analysis and geological database, threshold values will be predetermined which supports the WSN for decision making when the landslide events are occurred.

Landslides are a geological phenomenon that requires movement of earth, rock, and soil due to land erosion .Landslides have for decades posed to be risky as they destroy properties and even claim human lives[19]. Landslide, a frequently occurring natural hazard in the hilly terrains, shows majority of activity during the heavy rainfall. In India, over 49 million hectares (15% of land) is prone to landslide hazard[1][20].

2.5 Identification of hazard location

Landslide disaster occurs suddenly but it need long time gathering of disaster facts that changes the stability of the corresponding zone, The Landslide conditioning factors are selected based on previous research [21][22]. It can be used to identify the landslide hazard prone zone in the study area. They are Landuse, distance to roads, distance to railways, and distance to streams, slope angle, slope aspect, soil type, and rainfall.

III. STUDY AREA

The Nilgiri District of Tamil Nadu state has an area of about 2583 km^2 and is located between the longitudes 76°00'56"E and76°13'29"E and the latitudes 11°11'09"N and 11°42'01"N in the Western ghats. The Nilgiri Hills are part of a larger mountain chain known as the Western Ghats. Their highest point is the mountain of Doddabetta, height 2,633 m. The little territory is principally held back within this mountain range, with its headquarters at Ooty (Ootacamund or Udhagamandalam).It placed first in a comprehensive Economic Environment index ranking district in Tamil Nadu (not including Chennai) prepared by the Institute for Financial Management and Research in August 2009. In 2011, The Nilgiris had population of 735,394 (762,141 - year 2001). The sub-districts or Taluk of Nilgiris district Namely Gudalur, Udagamandalam, Pandalur, Kotagiri,Kundah and Coonoorhas

Population 105196, 191797, 125877, 108290, 46157 and 157754 respectively.

Landslide hazard map of India (1:6M scale) was prepared using GIS by the Building Materials Technology Promotion Council of India [23]. The map represents the degree of landslide prone zones in many regions of the nation, including Nilgiri district. Nevertheless, not considered a high level of detail such as roads and railways, etc. The steep hill slopes and heavy rainfall of the Nilgiri mountain, which generate landslides and debris flows. The deforestation in areas managed for urban development also tends to promote slope instability[24][21][25].

In that respects are different methods available for landslide zonation, every method has its own advantages and disadvantages. It has been observed in previous researches that no single method is able to describe long term detailed landslide zonation [26]. Nowadays, geospatial technology makes digital databases more and more available to decision makers[22][27]. The district is categorized under severe to very high landslide hazard prone areas[1], [23], [28]. In last few years, landslide susceptibility map was prepared using GIS and RS data such as fuzzy logic[29]–[32], expert system [33], Weighted Linear Combination [34][35]and artificial neural network methods have been applied by researchers in different countries[4], [20], [36]–[38].

Table 1: Normalized classes of landslide conditioning factors used

Factor (Weight)	Feature Class/ condition	Area in km^2	Percentage Area	Score
Landuse (0.1)	Water	31.45	1.22	0
	Dense Forest	674.23	26.19	1
	Reserved Forest	245.7	9.54	2
	Scrub	528.04	20.51	3
	Settlements	298.4	11.59	4
	Plantation	795.91	30.92	5
Road (Buffer distance) (0.1)	>120m	2358.24	91.25	1
	>80 m - ≤ 120 m	63.55	2.46	2
	<40 m – ≤ 80 m	72.78	2.81	3
	≤ 40 m	89.55	3.46	4
Railways (Buffer distance) (0.1)	> 120 m	2575.83	99.693	1
	>80 m - ≤ 120 m	2.63	0.102	2
	<40 m – ≤ 80 m	2.64	0.102	3
	≤ 40 m	2.63	0.101	4
Streams (Buffer distance) (0.1)	> 120 m	2181.96	84.31	1
	>80 m - ≤ 120 m	134.43	5.19	2
	<40 m – ≤ 80 m	135.54	5.24	3
	≤ 40 m	136.09	5.26	4

Table2: Normalized classes of landslide conditioning factors; Slope gradient, Slope Aspect and soil type.

Factor Name (Weight)	Class	Area in sq.km	Class Area in %	Score
	0 or Flat	14.14	0.55	0
Slope Gradient (0.25)	>0 - ≤ 10	1005.57	39.19	1
	>10 - ≤ 20	943.39	36.53	2
	>20 - ≤ 30	406.66	15.76	3
	>30 - ≤ 40	143.91	5.58	4
	>40	51.40	1.99	5
Slope Aspect (0.05)	North 337.5°–22.5°	394.85	15.48	1
	North west 292.5°–337.5°	333.55	13.08	2
	West 247.5°–292.5°	263.59	10.33	3
	East 67.5°–112.5°	312.79	12.26	4
	North East 22.5°–67.5°	304.12	11.92	5
	South East 112.5°–157.5°	345.37	13.54	6
	South 157.5°–202.5°	332.66	13.04	7
	South West 202.5°–247.5°	263.06	10.31	8
Soil Type (0.15)	Eutric Nitosols (Ne53-2ab)	599.59	23.21	1
	Lithosols (I-Nd-c)	391.10	15.14	2
	Plinthic Acrisols (Ap21-2b)	234.54	9.081	3
	Humic Acrisols (Ah11-2c)	1358.42	52.58	4
Rainfall (0.15)	0-1000 mm	242.82	9.63	1
	1000-1500 mm	758.15	30.08	2
	1500-2000 mm	663.02	26.31	3
	2000-2500 mm	554.60	22.01	4
	2500-3500 mm	301.39	11.96	5

According to the susceptibility analysis soil type similar to the study area are selected to set step down model slope for test bed. Behaviors of Rainfall based changing factors are to be monitor by deploying sensors in the test bed. Depends on the changes in the factors three levels (low level, middle level and high level) of threshold values are to be fixed[12]. The data aggregation by the sensor nodes are depends on this threshold values. According to the aggregated data from sensor nodes the gateway node send signal to the control unit. In control unit, sensor data are compared with the geological data, predetermined levels, and predict the probabilities of landslide occurrence.

IV. STEP DOWN MODEL SETUP:

Rain infiltration occurs under rainfall conditions, which increases the soil weight and reduces the shear strength of the soil. The slope failure can occur due to the water content of soil [39]. Based on the soil type and slope condition the model slope could be create and pour the artificial rainfall to identify the condition when the soil water content starts increase and the condition when the slope failure triggered with the help of wireless sensor networks due to the rainfall.

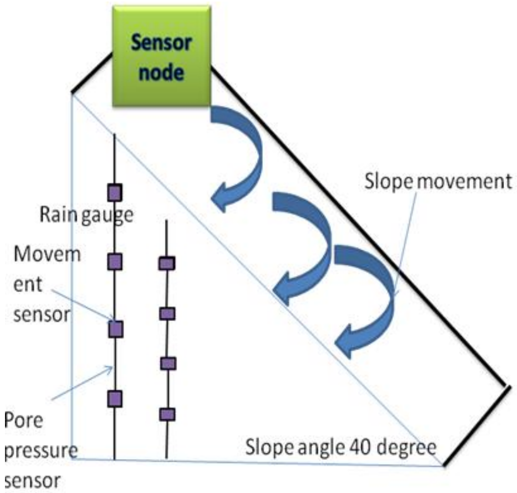

Table 5: conditions for model slop setup

2.6 Algorithm of landslide forecasting:

Routing protocol implementation is based on dynamic source routing (DSR) important property of DSR is that it does not transmit any periodic routing control packets and as a result there is no energy consumption imposed from the routing protocol during idle network periods[40].author [19], described the routing protocol has been modified in order to incorporate a power-aware routing (PAR) algorithm which makes routing decisions based on some energy efficient metric instead of the traditional shortest path criterion. At the link layer a low-power-mode (LPM) algorithm has been implemented. This protocol uses TCP sockets in order to support seamless communication among the sensor nodes and the central units and network management operations, a protocol [ad-hoc network management protocol (ANMP). The management entities use the ad-hoc network management service (ANMS), Wireless network interface, IEEE 802.11b DCF was chosen because it supports high transmission rates, there is availability of low cost products, and it is suitable for multi-hop ad hoc networks with reasonable power consumption.

V. CONCLUSION

Integration of energy efficient, threshold based data aggregation algorithm for wireless communication with different sensors is possible for the monitoring of slope (hazard zone) which can be identified by the GIS software. Identification of hazard zone avoid unwanted deployment of sensor nodes and landslide prediction data base which contains various landslide conditioning factors and threshold levels helps to analysis the monitoring information to suspect the occurrence of landslide.Further we focus our study on identification of landslide locations in the study area (Nilgiri district) and develop the slope model (based on the conditions) for predict the variations in the slope stability using sensors.

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