World Academy of Science, Engineering and Technology
International Journal of Electronics and Communication Engineering
Vol:1, No:12, 2007

Data Transmission Reliability in Short Message Integrated Distributed Monitoring Systems

Sui Xin, Li Chunsheng, and Tian Di

Abstract—Short message integrated distributed monitoring systems (SM-DMS) are growing rapidly in wireless communication applications in various areas, such as electromagnetic field (EMF) management, wastewater monitoring, and air pollution supervision, etc. However, delay in short messages often makes the data embedded in SM-DMS transmit unreliably. Moreover, there are few regulations dealing with this problem in SMS transmission protocols. In this study, based on the analysis of the command and data requirements in the SM-DMS, we developed a processing model for the control center to solve the delay problem in data transmission. Three components of the model: the data transmission protocol, the receiving buffer pool method, and the timer mechanism were described in detail. Discussions on adjusting the threshold parameter in the timer mechanism were presented for the adaptive performance during the runtime of the SM-DMS. This model optimized the data transmission reliability in SM-DMS, and provided a supplement to the data transmission reliability protocols at the application level.

Keywords—Delay, SMS, reliability, distributed monitoring system (DMS), wireless communication.

I. INTRODUCTION

DUE to geographical barriers and harsh working conditions, the traditional wired transmission (such as LANs [1]) is sometimes not a suitable solution in distributed monitoring systems (DMS). On the other hand, short message service (SMS), based on Global System for Mobile Communications (GSM), is developing at a rapid speed in wireless data communication [2]-[3].

The general framework of DMS is described in [4]. To meet different needs, DMS have been applied in various areas, such as submarine pipeline systems inspection [5], electromagnetic field (EMF) management [6]-[7], CT/MRI examination [8], and water quality supervision [9], etc.

With considerations of spatial distribution availability, flexibility, etc., applications of DMS have to employ different

options in communication solutions. Although the wired intranet works fine in some indoor applications [8], most others prefer to choose the wireless communication solutions. A review of these wireless options, together with discussions on their features, is provided in [10]. Various wireless applications, such as Satellite / cellular communication [11], blue-tooth [12] and GSM networks [13]-[18], have been developed.

As one of the wireless choices, SMS is notable for its economy and flexibility [19]-[20]. Trends and designs on using short messages are described in [2]-[3]. Some descriptions on SMS based applications are listed in [21]-[24].

To enhance the performance of the short messages integrated DMS (SM-DMS), current studies focus mainly on the network scale, such as the discussion on the overload control in the serving GPRS support node (SGSN) [25], etc. On the other hand, to guarantee the reliability in data transmission, studies chiefly concentrate on these two aspects:

- The communication protocols.
- The adaptive algorithms for Quality-of-Service (QoS) in transmission.

To the communication protocols aspect, a unified protocol in a GSM based project is described in [26], aiming to provide a standard in data acquisition on a general purpose. A policy for trade-off management on SMS Gateway congestions is discussed and realized in [27]. A network including wireless, cabled RS232, and Fast Ethernet transmission protocols with great flexibility to ensure modularity and connectivity is examined in [28].

To consider the QoS aspect, an overview of the existing adaptive algorithms and a test sample is provided in [29], whereas some specific ones can be found in [30].

In the SM-DMS, the control center, which sends commands to the data acquisition nodes to achieve data, plays a core role in the whole system. However, we find few descriptions on transmission delay processing towards the control center in both the SMS transmission protocols from ETSI [31] and current applications. To solve this problem, we present our design and implementation of a transmission model for the control center. In this model, we describe three methods: the data transmission protocol, the data receiving pool strategy, and the timer mechanism to guarantee the reliability of the data transmission in SM-DMS. This model also contributes to

World Academy of Science, Engineering and Technology
International Journal of Electronics and Communication Engineering
Vol:1, No:12, 2007

supplement the SMS transmission protocol in ETSI standards at the application level.

The remainder of this paper is organized as follows. The flowchart of the model, based on the analysis of the command and data requirements in SM-DMS, is presented in Section 2. The method details of the model are elucidated in Section 3. A discussion on adjusting the threshold parameter in the timer mechanism for adaptive performance to network environment changes is demonstrated in Section 4. The final section concludes this paper.

II. TRANSMISSION MODEL

In most DMS, it is a classic architecture that the control center of the system sends commands to achieve data from distributed data acquisition sensor nodes [21]-[24]. Consequently, sending commands and achieving data in a reliable way in the control center represents the principle requirements in SM-DMS. The model and the relevant methods descriptions in the following are chiefly devised for the usage of the control center.

The flowchart of the model is shown in Fig. 1. We developed three methods to guarantee the data transmission reliability in SM-DMS. Three methods in the model are described in detail in the next section.
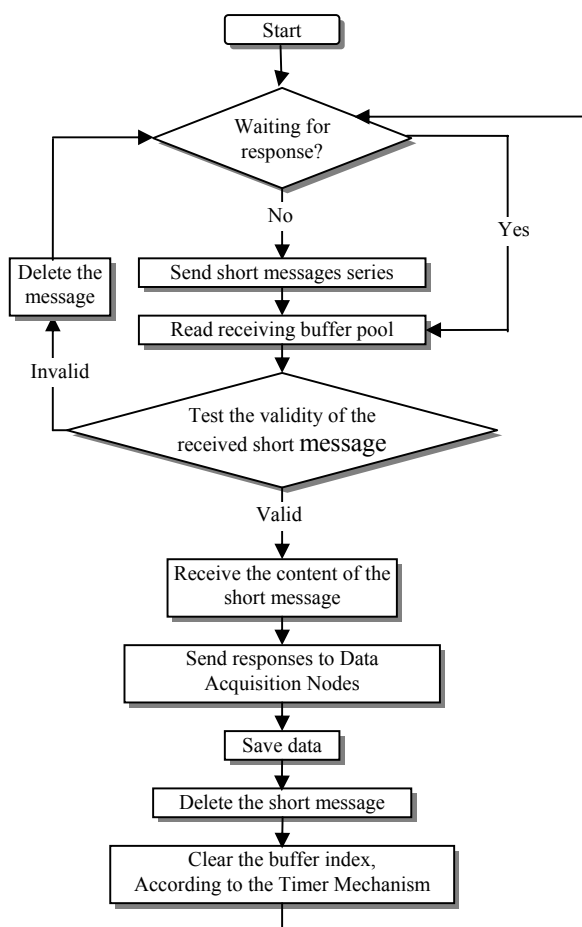

Fig. 1 Flowchart of the model

III. METHOD DETAILS

A. Data transmission protocol

The protocol is described in Fig. 2. It is composed of three parts: We employ it for both the control center to send commands and for the sensor nodes to transmit data.
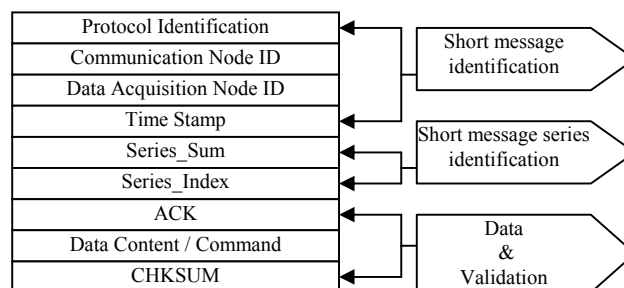

Fig. 2 Data transmission protocol

Part Ⅰ. short messages identification: functions as a "filter" in this protocol. By identifying the protocol's head, we can distinguish the valid short messages received from any invalid ones, thus ensuring the reliability of data transmission in SM-DMS. This part includes four items as follows:

● **Protocol Identification**: We employ it as a unique starting flag. The protocol version can be added here.

● **Communication Node ID**: We use it to uniquely identify the geographical area of the "Data Acquisition Nodes". It functions in two aspects: one is to identify the messages sent at the same time while from sensor nodes in different geographical areas. The other is to solve the time delay problem in Method B.

● **Data Acquisition Node ID**: We identify the short message originator (i.e., the acquisition sensor nodes or the control center) with the parameter.

● **Time Stamp**: We identify each short message with a uniquely created time stamp. When sending commands, the time stamp is set by the control center with its local time, whereas when receiving data, the communication nodes set their respective time stamp with their local time.

Part Ⅱ. short messages series identification: When we transmit command or data, it is common that the message length exceeds the length limit of one short message (i.e., 160 characters with 7-bit style or 140 characters with 8-bit style). To supplement the specifications in SMS protocols from ETSI [31] about this case, we provide a feasible solution in this part. The processing flowcharts of the send case and the receiving case are described in Fig. 3 and Fig. 4 respectively. The length of the message is n (e.g. n>140). This part includes:

● **Series_Sum**: We identify the total number of short messages series with this parameter.

● **Series_Index**: We identify the index of a certain message among short messages series with this parameter.

We guarantee the ordering and reliability by comparing and organizing the total number of Series_Index and the Series_Sum.
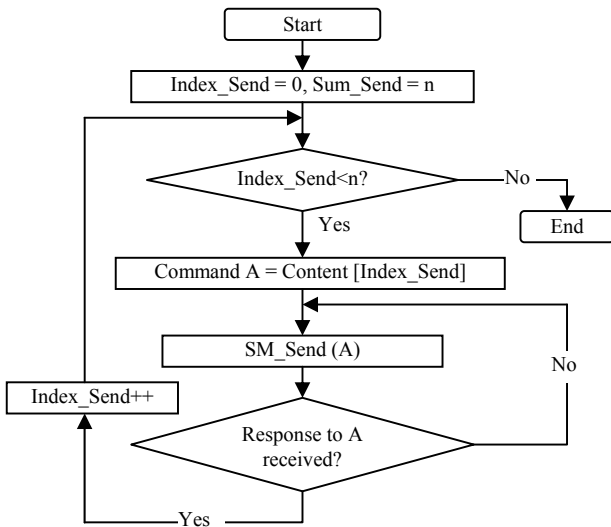
World Academy of Science, Engineering and Technology
International Journal of Electronics and Communication Engineering
Vol:1, No:12, 2007

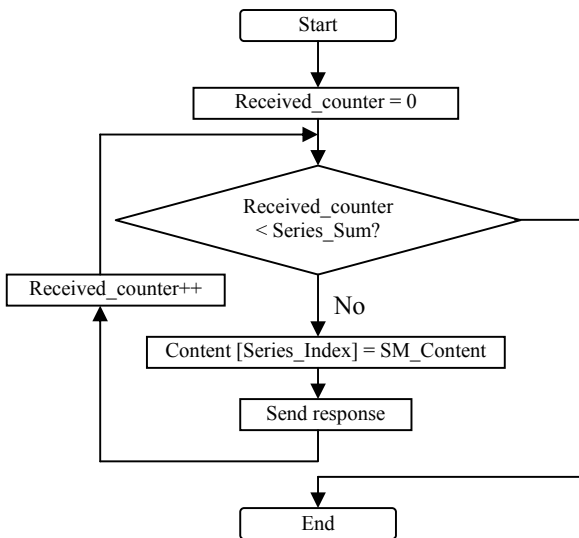Fig. 3 Short messages series—send case

Fig. 4 Short messages series—receiving case

Part Ⅲ: data & validation: We devise this part to verify the integration and validation of the Data Content / Command. According to the ACK flag, various meanings of the "Data Content / Command" column can be extracted. For example, if a message is verified to be correct, we may send a response message with "0x00" to ACK while leaving other parts in the protocol unchanged as the message received. This response message means that "a former message received is correct in format, please go on".

● **ACK**: We identify the type and function of the content in "Data Content / Command" column with this parameter.

● **Data Content / Command**: We store data from the acquisition sensor nodes or commands from the control center in the short messages with this parameter.

● **CHKSUM**: We ensure the validation and correctness of the content in "Data Content / Command" column with this

parameter.

B. Receiving buffer Pool

In the large-scale SM-DMS that many acquisition nodes are included, it is unavoidable that many communication nodes send messages almost at the same time, bringing communication traffic jams to the control center. Considering the physical capacity limit of GSM hardware modules, we raise two challenges here:

1) It is unable to predict the total number of the incoming messages.
2) It may lower the performance if the receiving buffer is defined too large or too small in the control center.

To meet Challenge 1), the "Receiving buffer Pool" method is investigated. It is used to achieve new, unique incoming messages from GSM hardware modules. We focus on efficiently and economically making adequate buffer for new incoming messages to compensate the GSM hardware physical capacity limit. To achieve this, a message filter is developed.

The message filter: used to filter out the duplicated short messages that already existed in the buffer pool from the incoming messages in the GSM hardware module. The criterion of the filter is a flag composed of the "time stamp", the "Data Acquisition Node ID", and the "Communication Node ID". The flag is chosen based on the analysis to these possible cases:

a) Messages received are marked with the same "time stamp": happens when the acquisition nodes distributed in different geographical areas send messages at the same time according to the local time in their respective communication modules. In this case, the "communication node ID" assists to identify the different areas.

b) Other sorts of messages besides those in case a): a unique identification composed of the "time stamp" and the "Data Acquisition Node ID" solves this case well.

Messages passing the filter then are new and unique in the buffer pool, and can be stored and processed according to the steps shown in Fig. 5.
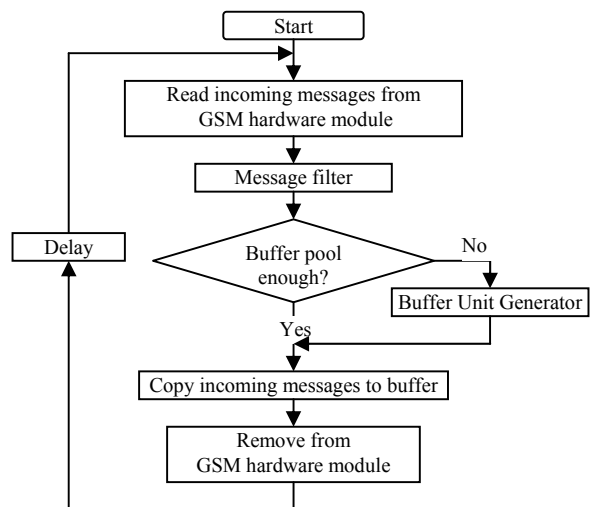

Fig. 5 Workflow of the receiving buffer pool

World Academy of Science, Engineering and Technology
International Journal of Electronics and Communication Engineering
Vol:1, No:12, 2007

To meet Challenge 2): We developed a loop management to take care of the buffer size automatically. In one reading cycle, if there is no adequate buffer space in the buffer pool for new messages, the buffer unit generator is called to create new space for the rest operations. Then, the original message is deleted from the GSM hardware module to accommodate new incoming messages in the next cycle. Once a message in the buffer pool is processed properly (e.g. stored in databases), the buffer space for that message is immediately cleared but not deleted for further messages in case that buffer pool grows too large when calling the buffer unit generator. In addition, one cycle is delayed for a while between the next, which enables the GSM hardware module to receive new short messages, and set aside enough time to analyze messages in the buffer pool according to data transmission protocols.

C. Timer Mechanism

According to our practical tests in the project, messages sent are often be delayed for some time (such as several hours). This is primarily due to the inadequate capacity of the SMSC or geographical conditions that weaken the GSM signal. To solve the delay problem effectively, we introduced a timer mechanism as a supplement to the standard SMS protocol [31]. This mechanism works in cycles called timer cycles.

A) Hypothesis

1) Before the SM-DMS actually work, we do sample tests for the message-response pairs in standard conditions (i.e., without any changes or disturbances to the short messages transmission) and define:

- $\tau(t)$: A set of delay values within a given period (such as an hour). According to our tests, its value is mainly affected by these two factors:
  a) The geographical locations of the control center / data acquisition nodes.
  b) The time of day when we send the message.

- $Max[\tau(t)]$: The timer threshold. It is the maximum time the model can tolerate the delay of a message. We choose it from $\tau(t)$ sample values according to Poisson distribution rules [32].

2) When the control center sends Message A in actual working conditions, we define:

- t_1 : The moment when the message is sent. A timer cycle begins at this moment.

- t_2 : The moment when the receiving buffer pool finishes a reading cycle each time. A timer cycle ends at this moment.

- $\delta(t)$: The duration during which the control center waits for the response of Message A after t_1 in actual conditions.

B) Principle description

Commands and responses in SM-DMS are regulated in message-response pairs. We describe the mechanism in two stages:

Stage a): Preparation.

Before the SM-DMS actually run, we measure a set of $\tau(t)$ values as sample values to determine $Max[\tau(t)]$ for the threshold in timer cycles.

Stage b): During runtime, e.g., in a timer cycle.

A timer cycle starts when Message A is sent at t_1. The control center then waits for the response by reading throughout the receiving buffer pool for several times until the end of the cycle. Each time the reading progress ends at moment t_2, $\delta(t)$ is calculated with $\delta(t) = t_2 - t_1$.

If $\delta(t) < Max[\tau(t)]$ and the correct response arrives, we assume that Message A is successfully sent in this timer cycle and send the next message in request. Or else we continue reading the receiving buffer pool for another time and do the same comparison when each reading progress ends. If $\delta(t)$ exceeds $Max[\tau(t)]$, we assume that Message A sending fails for one time, then repeat the progress. If the repeat time exceeds some limit, such as four (we adjust it according to the performance of the SM-DMS in actual conditions), we assume that Message A sending fails in this timer cycle and suggest the user to send Message A later. Incorrect responses are deleted.

IV. DISCUSSION

Previously, $\tau(t)$ is achieved from sample tests before the SM-DMS actually run. As the GSM network environment changes, such as the augment of physical capacity in SMSC, we then have to adjust $\tau(t)$ by stopping the SM-DMS and do the sample measurements again to choose a new $Max[\tau(t)]$. However, there is an alternative according to the transaction reports in the SMS protocol for its adaptive adjustment [31], [19]-[20].

The SMS transaction reports workflow is described in Fig. 6. The workflow is sequentially indexed with numbers from 1 to 5 corresponding with its actual working order.
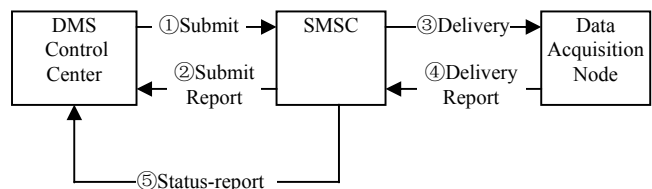

Fig. 6 SMS Transaction Reports

We define t_3 as the moment when we receive the status-report (a report sent by SMSC indicating the successful

World Academy of Science, Engineering and Technology
International Journal of Electronics and Communication Engineering
Vol:1, No:12, 2007

delivery or failure of a previously submitted message sent from the DMS Control center to the Data Acquisition Node). Definitions to other reports are described in [31]. Two cases may occur here:

Case a): The transaction reports workflow is completed normally. In such a case, we can calculate $\tau(t)$ with the formula $\tau(t) = t_3 - t_1$.

Case b): The transaction reports workflow is broken off somewhere, causing status-report lost and we cannot attain t_3 even when $\delta(t)$ grows equal to or larger than $Max[\tau(t)]$, which indicates the network is busy or malfunction for some reasons. In such a case, $\tau(t)$ is assessed at the current $Max[\tau(t)]$ value, and we end this timer cycle and suggest the user to send Message A later.

Based on the discussions above, we then do not have to stop the SM-DMS to measure the new $Max[\tau(t)]$ for timer threshold with the help of SMS transaction reports, thus making the $Max[\tau(t)]$ parameter change itself adaptively to the working conditions.

However, we noticed the fact that transaction reports capabilities are optional to SMSC operators [31], which limits the DMS deployment feasibility and flexibility. As a result, we consider it an optional choice for SM-DMS in different areas.

V. CONCLUSION

We applied this model in the sponsored project to monitor wastewater quality in rural areas and achieved better performance in data transmission reliability. By taking advantage of the model, we can extend it in other similar SM-DMS applications.

REFERENCES

[1] W. Stallings, *Local and metropolitan area networks*, 4th Edition, Macmillan Publishing Company, 1993

[2] Jia. Hong-Yu, Zhao. Jun-Feng, and Xiaoxing Weixing, "Principle and design of the short message service platform", *Jisuanji Xitong/Mini-Micro Systems*, vol. 24, no.5, pp. 819, May. 2003

[3] Yan. Xu, "Mobile data communications in China", *Communications of the ACM*, v46, no.12, pp. 80-85, Dec. 2003

[4] Ribeiro. Joao Araujo, De Farias. Oscar Luis Monteiro, and Roque. Luiz Alberto Oliveira Lima, "A framework for environmental monitoring information systems", in *International Geoscience and Remote Sensing Symposium (IGARSS)*, v6, *2004 IEEE International Geoscience and Remote Sensing Symposium Proceedings: Science for Society: Exploring and Managing a Changing Planet. IGARSS 2004*, 2004, pp. 3603-3606

[5] Jin. Wei-Liang, Shao. Jian-Wen, and Zhang. En-Yong, "Basic strategy of health monitoring on submarine pipeline by distributed optical fiber sensor", in *Proceedings of the International Conference on Offshore Mechanics and Arctic Engineering - OMAE*, vol. 2, 2003, pp. 531-536

[6] Bucci.G, Fiorucci. E, and Landi. C, "Digital measurement station for power quality analysis in distributed environments", in *Conference Record - IEEE Instrumentation and Measurement Technology Conference*, vol. 1, 2001, pp. 368-373

[7] De Capua. C, Morello. R, and Pasquino. N, "A mobile distributed architecture for measurement and analysis of the electromagnetic field", in *Conference Record - IEEE Instrumentation and Measurement Technology Conference*, vol. 3, *Proceedings of the 21st IEEE Instrumentation and Measurement Technology Conference, IMTC/04*, 2004, pp. 2090-2094

[8] Ratib. Osman, Dahlbom. Maggie, Zucek. Jamie M, Kong. Kinchi, McCoy. Michael, Valentino. and Daniel J, "Web-based video for real-time monitoring of radiological procedures", *IEEE Transactions on Information Technology in Biomedicine*, vol. 4, no. 2, pp. 108-115, Jun, 2000

[9] Girao. P. Silva, Pereira. J.M. Dias, Ramos. Helena, and Postolache. O, "Wireless water quality monitoring system based on field point technology and kohonen maps", in *Canadian Conference on Electrical and Computer Engineering*, vol. 3, 2003, pp. 1873-1876

[10] Egea-Lopez. Esteban, Martinez-Sala. Alejandro, Vales-Alonso. Javier, Garcia-Haro. Joan, and Malgosa-Sanahuja. Josemaria, "Wireless communications deployment in industry: a review of issues, options and technologies", *Computers in Industry*, vol. 56, no. 1, pp.29-53, Jan. 2005

[11] Chronis. George Th., Poulos. Seraphim, and Soukissian. Takvor H, "POSEIDON: Marine environmental, monitoring, forecasting and information system for Greek waters", *Oceans Conference Record (IEEE)*, vol. 3, pp.1529-1530, 1998

[12] Wu. Zhengzhong, Zhong. Xianxin, Yu. Wenge, and Li. Xiaoyi, "Real-time wireless sensor networks for civil structure safety monitoring", in *Progress in Safety Science and Technology Volume 4:Proceedings of the 2004 International Symposium on Safety Science and Technology*, n PART B, *Progress in Safety Science and Technology Volume 4: Proceedings of the 2004 International Symposium on Safety Science and Technology*, 2004, pp. 2194-2199

[13] Bonastre. A, Ors. R, Capella. J.V, Fabra. M.J, and Peris. M, "In-line chemical analysis of wastewater: present and future trends", *TrAC - Trends in Analytical Chemistry*, vol. 24, no. 2, pp.128-137, Feb. 2005

[14] Al-Ali, Abdul-Rahman, Khaliq. Abdul, and Arshad. Muhammad, "GSM-based distribution transformer monitoring system", in *Proceedings of the Mediterranean Electrotechnical Conference - MELECON*, v3, *Proceedings of the 12th IEEE Mediterranean Electrotechnical Conference, MELECON 2004*, 2004, pp. 999-1002

[15] Jurkovic. Gpran and Zagar. Mario, "GSM wireless solutions in distributed embedded systems designed for automatic control", in *Proceedings Elmar - International Symposium Electronics in Marine, Proceedings Elmar-2004 - 46th International Symposium Electronics in Marine*, 2004, pp. 205-210

[16] Chen. J.-F, Lin. W.Ch, Chung. C.M, Tsai. K.H, Chang. C.H, and Hu. W.Ch, "Distributed monitoring architecture for movable objects over the GSM system", in *Proceedings of SPIE - The International Society for Optical Engineering*, vol. 4311, 2001, pp. 301-310

[17] Lloyd. Glynn, Everall. Lorna, Sugden. Kate, and Bennion. Ian, "A high-performance miniaturized time division multiplexed sensor system for remote structural health monitoring", in *Proceedings of SPIE - The International Society for Optical Engineering*, vol. 5459, Optical Sensing, 2004, pp. 145-156

[18] Elouardi. N, Steuer. J, Radimirsch. M, Fette. H, and Jobmann. K, "Proactive dynamic resource distribution based on borrowing and control engineering methods for GSM-like systems", in *IEEE International Symposium on Personal, Indoor and Mobile Radio Communications, PIMRC*, vol. 2, 2000, pp. 1348-1352

[19] Peersman. Guillaume, Cvetkovic. Srba, Griffiths. Paul, and Spear. Hugh, "Global system for mobile communications short message service", *IEEE Personal Communications*, vol. 7, no. 3, pp. 15-23, Jun. 2000

[20] M.Rahnema, "Overview of the GSM system and protocol architecture". *IEEE Comm.* 31(3), pp. 92--100, Apr. 1993

[21] Lee. Jin-Shyan and Hsu. Pau-Lo, "Design of remote environmental monitoring systems", in *IEEE Conference on Control Applications - Proceedings*, vol. 2, 2002, pp. 856-861

World Academy of Science, Engineering and Technology
International Journal of Electronics and Communication Engineering
Vol:1, No:12, 2007

[22] Zappala. G., "A software set for environment monitoring networks", *Environmental Studies*, vol. 11, *Development and Application of Computer Techniques to Environmental Studies X*, pp. 3-12, 2004

[23] Chen. Yih-Fan, Wu. Wen-Jong, Chen. Chun-Kuang, Wen. Chih-Min, Jin. Ming-Hui, Gau. Chung-Yun, Chang. Chih-Chie, and Lee. Chih-Kung, "Design and implementation of smart sensor nodes for wireless disaster monitoring systems", in *Proceedings of SPIE - The International Society for Optical Engineering*, vol. 5391, *Smart Structures and Materials 2004 - Sensors and Smart Structures Technologies for Civil, Mechanical, and Aerospace Systems*, 2004, pp. 798-805

[24] Steere. David C, Baptista. Antonio, McNamee. Dylan, Pu. Calton, and Walpole. Jonathan, "Research challenges in environmental observation and forecasting systems", in *Proceedings of the Annual International Conference on Mobile Computing and Networking, MOBICOM*, 2000, pp. 292-299

[25] Haung. Yieh-Ran, Ho.Jan-Ming, "Overload control for short message transfer in GPRS/UMTS networks", *Information Sciences*, vol. 170, no. 2-4, pp. 235-249, Feb. 2005

[26] Ozkul, Tarik and Al Homoud.A, "Communication protocol for monitoring a large number of remotely distributed hazardous material detection devices", *Computer Standards and Interfaces*, vol. 25, no. 5, pp. 553-561, September. 2003

[27] Prieto. Alberto Gonzalez, Cosenza. Roberte, Stadier. Rolf, "Policy-based congestion management for an sms gateway", in *Proceedings - Fifth IEEE International Workshop on Policies for Distributed Systems and Networks, POLICY 2004*, 2004, pp. 215-218

[28] Barone. Fabrizio, De Rosa. Rosario, Milano. Leopoldo, and Kipiani. Ketevan, "A distributed multiprotocol acquisition network for environmental data", in *Proceedings of SPIE - The International Society for Optical Engineering*, vol. 4886, 2002, pp. 605-613

[29] Friday. A, Davies. N, Blair. G.S, and Cheverst. K.W.J, "Developing adaptive applications: The most experience", *Integrated Computer-Aided Engineering*, vol. 6, no. 2, p143-157, 1999

[30] Elouardi. N, Steuer. J, Radimirsch. M, Fette. H, and Jobmann. K, "Proactive dynamic resource distribution based on borrowing and control engineering methods for GSM-like systems", in *IEEE International Symposium on Personal, Indoor and Mobile Radio Communications, PIMRC*, vol. 2, 2000, pp. 1348-1352

[31] *European digital cellular telecommunication systems (phase 2+), technical realisation of the short message service (SMS), point-to-point, GSM*, ETSI (European Telecommunications Standards Institute), *03.40* version 7.1.0, Release 1998

[32] Al-Begain. K, Awan. I, and Kouvatos. D.D, "Analysis of GMS/GPRS cell with multiple data service classes", *Wireless Personal Communications*, vol. 25, no. 1, pp.41-57, April. 2003

Sui Xin is currently studying at the Department of Instrumentation Science and Electrical Engineering, Jilin University, Changchun City, Jilin Province, China, People's Republic of. He received his B.S. degrees in Electrical Engineering from Jilin University in 2003. He is now studying for his M.S. degrees. His research interests focus on algorithms, architectures, and protocols, etc on controlling systems in distributed network.

Li Chunsheng is working at the Department of Instrumentation Science and Electrical Engineering in Jilin University, Changchun City, Jilin Province, China, People's Republic of. He received his B.S. degrees in Electrical Engineering from Peking University in 1995. Since 1998, he has been working as an instructor in Jilin University. His research interests focus on wireless communication and embedded systems.

Tian Di is currently a full professor of the Department of Instrumentation Science and Electrical Engineering, Jilin University, Changchun City, Jilin Province, China, People's Republic of. He received his B.S. degrees in Wireless Communication and M.S. degrees in Electromagnetic Fields Measurement and Instrumentation Science from Changchun College of Geology in 1978 and 1990 respectively. He received his Ph.D. degrees in Optical Engineering from Changchun Institute of Optics, Fine Mechanics and Physics, Chinese Academy of Sciences in 1995. His research interests focus on analytical instrumentation science and controlling systems in distributed network.