

Wireless Networking and Mobile Data Management

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This book is dedicated to three wonderful persons.

To my teacher Professor G. P. Bhattacharjee, who believed that my achievements were not accidental but both expected and deserved.

To my wife Sarbani and to my daughter Ritwika. Without their support and understanding it would not have been possible. At times Sarbani felt the book will never appear in print though my little one never expressed it in so many words, perhaps she believed her mom.

Preface

This book grew out of the class notes around which a course on mobile computing was taught to the senior undergraduate and the masters' students at IIT Kanpur. These students unknowingly became guinea pigs in the process of my understanding of the subject.

The certain topics included in this book have been produced in different forms distributed over a number of other books or collections. In that sense, the uniqueness of the current text lies in putting the contents in an understandable form woven through a single thread. Giving a different orientation to the work of others is not quite easy. Most of the times I felt that the original text of the work is perhaps the best way to communicate. However, while teaching certain material in the class, a few interesting ideas emerged out of the queries by the students. These ideas provided cues for improved presentations. Maybe a discernable reader will find that some of the topics in this book have been presented in sufficient details, while a few other topics perhaps could have been presented in a better way. Specially, I feel a reasonable understanding of smart environment would require more space than I could allocate in this book. In trying to fit it within the scope of the book, context-aware infrastructure became a dominant theme in my presentation. However, I believe that building smart environment, in itself, is an engineering problem which is understood best by practice than by learning through literature or a book.

The book is organized into two parts consisting eight chapters each. Part I deals with wireless networking, while Part II addresses mobile data management issues. The effort was to strike a balance between the two parts and provide the readers what I believe is a comprehensive treatment of the subject. The material for the mobile data management part was more or less gathered directly from the original articles, as most of the available books in the area at the time when I start writing this book were just unrelated collections of research literature. Fortunately, there are many excellent texts on wireless networking part. But, these books were written with the target audiences having background either in electrical engineering or in physics. Very few books, if at all, dealt with protocol level details in somewhat sketchy manner. However, these texts did substantially influence the material presented in first part of the book. My class notes gradually developed over the

years and matured somewhat unconsciously in the form a monograph as it appears now.

Chapter 1 of the book is an introduction to mobile distributed environment and some interesting innovative applications in the area. Instead of a conventional introduction to book, this chapter provides the reader a general understanding of the issues that arise in the context building pervasive mobile applications and smart environment. The subsequent five chapters deal with the range of wireless networking technologies. It includes cellular-based wireless communication, telecommunication protocols such as GSM, GPRS, and UMTS, and short-range radio communication protocols such as WLAN, Bluetooth, IR, ZigBee, and 6LoWPAN. The remaining two chapters of the first part deal with routings in mobile ad hoc network, mobile operating systems and application-level protocols such as Mobile IP, WAP, and Mobile Shell (Mosh).

Part II of the book deals with mobile data management. This part begins with a chapter on WSN-related protocols, namely routing, interoperability, and multi-sensor integration. Though the contents of the chapter appear to lean more toward network than data, the two main reasons for clubbing it with mobile data management are as follows: (i) WSNs unlike IP-based network are data-centric networks and (ii) multisensor integrations employ sophisticated mathematical tools for fusion of data. More precisely, data is used as a communication token for routing in WSN. On the other hand, data fusion requires rich mathematical techniques that deal with detection, association, correlation, estimation, and combination of sensory data. The next chapter deals with the techniques for location management in GSM-type network for tracking personal and terminal mobilities. Here again, the decision to classify the chapter under mobile data management part is driven by the fact that the volume of location data far exceeds the size of a database that can be handled by a conventional database application. Specially, capturing location data related to personal mobility requires interesting data management and machine learning techniques. The remaining topics related to mobile distributed environment included in this part are as follows: design of algorithms, data dissemination, indexing, caching, replications, and storage management. The last chapter of the book does not directly deal with data management issues, but it talks about context-aware infrastructure for building smart environments.

The pre-requisite relationships between the contents of chapters are shown in Fig. 1. The solid lines show direct dependencies, and dotted line indicates indirect dependencies of the chapters. The book is written in a way, so that it does not require any pre-requisite other than the standard undergraduate knowledge of computer networks and algorithms. Having a bit of working knowledge about operating system (OS) could also help the reader to understand some of the practical issues described in the context of building mobile distributed applications.

The subject matter of the book has been chosen with a balanced assessment of the requirements of a target audience that would consist of senior undergraduates, masters, as well as research students. Practicing engineers perhaps may not get particularly excited about the book, as most of the content as well as the treatment

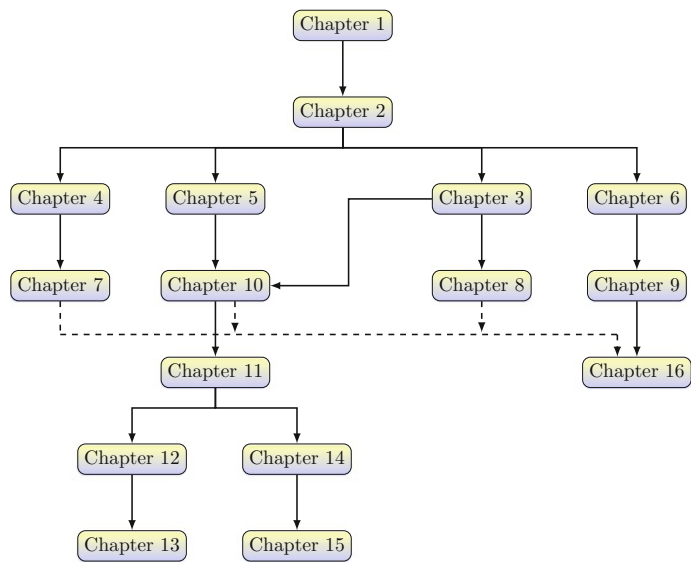


Fig. 1 Pre-requisite structure of chapters

of the contents is biased more toward theory than implementation. However, I believe that the chapter on smart environment and context-aware computing would provide a few pointers to ideas on leveraging mobile cloud computing for building smart applications.

Kanpur, India
December 2016

R.K. Ghosh

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About the Author

R.K. Ghosh is a professor in the Department of Computer Science and Engineering at the Indian Institute of Technology Kanpur. Earlier, he held a professor's position in the Department of Computer Science and Engineering at the Indian Institute of Technology Guwahati. A few of the other positions he has held in the past include a UN teacher fellow at the International Institute for Software Technology (IIST) Macau, a visiting scientist at INRIA Sophia Antipolis, France, and a visiting faculty in the Department of Computer Science at the University of Texas at Arlington, USA. His primary research interests are in mobile computing, distributed systems, and wireless networks.

Dr. Ghosh has published extensively in professional journals on wireless sensor networks, mobile applications and services, parallel and distributed systems, graph theory, and the operation of large data centers. He has co-authored one book and edited several conference proceedings, as well as authored a few book chapters in the general area of mobile applications and services. Dr. Ghosh has worked on several sponsored research projects related to parallel processing, distributed software engineering, mobile computing and cloud computing. A few of these projects involved international collaborations with the researchers from the University of Trento, Italy, Airbus Industrie, France, Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia, University of Melbourne, Australia, and University of Texas at Arlington, USA. His pedagogic interests led to a collection of animation programs for teaching data structure and algorithms at the undergraduate level. A partial collection of these animation programs grouped as Ghosh's collection is available at <http://algoviz.org/node/641>.

Acronyms

3G	Third Generation
3GPP	Third-Generation Partnership Project
4G	Fourth Generation
5G	Fifth Generation
6LoWPAN	Low-power Network on IPv6
8-PSK	Octagonal Phase-Shift Keying
ABR	Associativity-Based Routing
ACCH	Associated Control CHannels
ACL	Asynchronous Connection Less
ACO	Augmented Channel Occupancy
AGCH	Access Grant CHannel
AMA	Active Member Address
AODV	Ad hoc On-Demand Distance Vector
AP	Access Point
API	Application Programming Interface
APL	APplication Layer
ARP	Address Resolution Protocol
ARQ	Automatic Repeat reQuest
AU	Application Unit
AuC	Authentication Center
BCCH	Broadcast Control CHannel
BCH	Broadcast CHannel
BCO	Borrowing with Channel Order
BER	Bit Error Rate
BFA	Borrow from the First Available
BFR	Borrowing From the Richest
BS	Base Station
BSA	Basic Service Area
BSC	Base Station Controller
BSS	Base Station Subsystem

BSS	Basic Service System
BSSAP	Base Station System Application Part
BSSGP	BSS GPRS application Protocol
BSSID	BSS Identifier
BTS	Base Transceiver Station
CAC	Channel Access Code
CAN	Community Area Network
CASS	Context-Aware Substructure System
CCCH	Common Control CHannels
CDMA	Code Division Multiple Access
CEPT	Conference of European Post and Telecommunication
CFP	Contention-Free Period
CGI	Common Gateway Interface
CGSR	Cluster Gateway Switch Routing
CoA	Care-of Address
CoAP	Constrained Application Protocol
CoBrA	Context Broker Architecture
CODA	COntant Data Availability
CRC	Cyclic Redundancy Code
CS	Circuit Switching
CSCF	Control Session Control Function
CSMA/CA	CSMA with Collision Avoidance
CSMA	Carrier Sensing and Multiple Access
CTS	Clear to Transmit
DAC	Device Access Code
DAO	Destination Advertisement Object
DCA	Dynamic Channel Assignment
DCCH	Dedicated Control CHannels
DCF	Distributed Coordination Function
DDCA	Distributed Dynamic Channel Assignment
DHCP	Dynamic Host Control Protocol
DIFS	DCF Inter-Frame Spacing
DIO	DODAG Information Object
DIS	DODAG Information Solicitation
DISCUS	Distributed Source Coding Using Syndromes
DODAG	Destination-Oriented Directed Acyclic Graph
DoS	Denial of Services
DRNC	Drift RNC
DSC	Distributed Source Coding
DSDV	Destination-Sequenced Distance Vector
DSR	Dynamic Source Routing
DSSS	Direct-Sequence Spread Spectrum
DTD	Document-Type Definition
DTX	Discontinuous Transmission
EDGE	Enhanced Data rates for GSM Evolution

EIR	Equipment Identity Register
ESS	Extended Service Set
ETSI	European Telecommunication Standard Institute
ETX	Expected Transmission count
EUI	Extended Unique Identifier
FA	Foreign Agent
FAC	Final Assembly Code
FACCH	Fast Associate Control CHannel
FCA	Fixed Channel Assignment
FCCH	Frequency Correction CHannel
FCS	Frame Check Sequence
FDD	Frequency Division Duplex
FDMA	Frequency Division Multiple Access
FEC	Forward Error Correction
FFD	Full Function Device
FFH	Fast Frequency Hopping
FHSS	Frequency Hopping Spread Spectrum
FSR	Fish-eye State Routing
FTP	File Transfer Protocol
GEAR	Geographical and Energy-Aware Routing
GGSN	Gateway GPRS Support Node
GMM	GPRS Mobility Management
GMSC	Gateway MSC
GoS	Grade of Service
GPRS	General Packet Radio Service
GPS	Geographical Positioning System
GPSK	Gaussian Phase-Shift Keying
GRPH	GRouP Hello
GSM	Groupe Speciale Mobile
GSR	Global State Routing
GTP	GPRS Tunneling Protocol
HA	Home Agent
HEC	Header Error Check
HLR	Home Location Register
HRN	Handover Reference Number
HSCSD	High-Speed Circuit-Switched Data
HSS	Home Subscriber Service
HTML	Hypertext Mark-up Language
HTTP	Hypertext Transfer Protocol
IAC	Inquiry Access Code
IAM	Initial Address Message
IARP	IntrAzone Routing Protocol
IAS	Information Access Service
IBSS	Independent BSS
ICMP	Internet Control Message Protocol

IEEE	Institute of Electronics and Electrical Engineers
IERP	IntErzone Routing Protocol
IFH	Intermediate Frequency Hopping
IMEI	International Mobile Equipment Identity
IMSI	International Mobile Subscriber's Identity
IoT	Internet of Things
IP	Internet Protocol
IPv4	Internet Protocol version 4
IPv6	Internet Protocol version 6
IR	Infrared
ISDN	Integrated Service Digital Network
L2CAP	Logical Link Access Protocol
LAI	Location Area Identifier
LAN	Local Area Network
LAP	Link Access Protocol
LAPD	Link Access Protocol for ISDN D-Channel
LAR	Location-Aided Routing
LIX	LRU PIX
LLC	Link Logical Layer
LLN	Low-power Lossy Network
LM-IAS	Link Management Information Access Service
LM-MUX	Link Management MULTipleXing
LMP	Link Manager Protocol
LMR	Lightweight Mobile Routing
LODA	Locally Optimized Dynamic Assignment
LRU	Least Recently Used
LS	Location Server
LSAP	Link Service Access Point
LSAP-SEL	Link Service Access Point SElector
M2M	Machine to Machine
MAC	Medium Access Control
MAC	Medium Control Adaptation Protocol
MACT	Multicast route ACTivation
MANET	Mobile Ad hoc Network
MAP	Mobile Application Protocol
MCC	Mobile Cloud Computing
MDS	Mobile Distributed System
MGCF	Media Gateway Control Function
MGW	Media Gateway
MH	Mobile Handset
MIMO	Multiple-Input and Multiple-Output
MLME	MAC layer Management Entity
MN	Mobile Node
MOC	Mobile Originating Call
Mosh	Mobile shell

MS	Mobile Station
MSC	Mobile Switching Center
MSISDN	Mobile Station ISDN
MSRN	Mobile Station Roaming Number
MT	Mobile Terminal
MTC	Mobile Terminated Call
MTP	Message Transport Part
MTU	Maximum Transmission Unit
NAV	Network Allocation Vector
NCH	Notification CHannel
NDM	Normal Disconnected Mode
NLA	Next-Level Aggregator
NLME	Network Layer Management Entity
NRM	Normal Response Mode
NSAPI	Network Service Access Point Identifier
NSS	Network Subsystem
NWK	NetWoRK layer
OBEX	OBject EXchange protocol
OBU	Onboard Unit
OCB	Office Code Book
OFDM	Orthogonal Frequency Division Multiplexing
OSI	Open System Interconnection
OVSF	Orthogonal Variable Spreading Factor
PAN	Personal Area Network
PCF	Point Coordination Function
PCH	Paging CHannel
PDA	Personal Digital Assistant
PDN	Packet Data Network
PDU	Protocol Data Unit
PHY	Physical Layer
PIFS	PCF Inter-frame Spacing
PIMSI	Packet IMSI
PIN	Personal Identity Number
PIX	Probability Inverse frequency X
PLL	Physical Link Layer
PLMN	Public Land Mobile Network
PMA	Passive Member Address
PMS	Power Management System
PS	Packet Switching
PSTN	Public Switched Telephone Network
QoS	Quality of Service
QSPK	Quadrature Phase-Shift Keying
RAB	Radio Access Bearer
RACH	Random Access CHannel Associativity-Based Routing
RAI	Routing Area Identification

RERR	Route ERRor packet
REST	REpresentational State Transfer
RETOS	Resilient, Expandable, and Threaded Operating System for Wireless Sensor Networks
RFD	Reduced Function Device
RFID	Radio Frequency IDentification
RLC	Radio Link Control
RNAAP	Radio Network Access Application Part
RNC	Radio Network Controller
RNC	Regional Network Center
RNL	Radio Network Layer
RoLL	Routing over Low-power and Lossy networks
RPL	Routing Protocol for Low-power and lossy networks
RREP	Route REPLY packet
RREQ	Route REQuest packet
RRM	Radio Resource Manager
RSS	Received Signal Strength
RSSI	RSS Indicator
RSU	Road Side Unit
RTS	Request to Transmit
RTT	Round-Trip Time
SACCH	Slow Associated Control CHannel
SCCP	Signaling Connection Control Part
SCH	Synchronization CHannel
SCO	Synchronous Connection Oriented
SDDCH	Stand-alone Dedicated Control CHannel
SDP	Service Discovery Protocol
SFH	Slow Frequency Hopping
SGSN	Servicing GPRS Support Node
SIFS	Short Inter-Frame Spacing
SIM	Subscriber Identity Module
SIR	Signal-to-Interference Ratio
SLA	Site-Level Aggregator
SLP	Service Location Protocol
SMS	Short Messaging Service
SNDCP	Subnetwork Dependent Convergence Protocol
SNPDU	Subnetwork Dependent Protocol Data Unit
SNR	Signal-to-Noise Ratio
SOCAM	Service-Oriented Context Middleware
SPIN	Sensor Protocol for Information via Negotiation
SRNC	Servicing RNC
SS	Supplementary Service
SSH	Secure SHell
SSID	Service Set Identifier
SSL	Secure Socket Layer

SSP	State Synchronization Protocol
SSR	Signal Stability Routing
TAC	Type Approval Code
TCAP	Transaction Capability Application Part
TCH	Traffic CHannel
TCP	Transmission Control Protocol
TCS	Telephone Control Specification
TDD	Time-Division Duplex
TDMA	Time-Division Multiple Access
TIMSI	Temporary IMSI
TLA	Top-Level Aggregator
TLS	Transport Layer Security
TNL	Transport Network Layer
TORA	Temporarily Ordered Routing Algorithm
TRAU	Transcoder and Rate Adaptation Unit
TSN	Transient Social Networking
TTL	Time To Live
TTP	Tiny Transport Protocol
UCAM	Unified Context-Aware Application Model
UDP	User Datagram Protocol
UE	User Equipment
UMTS	Universal Mobile Telecommunication System
URL	Uniform Resource Locator
UTRAN	UMTS Terrestrial Radio Access Network
UUID	Universally Unique IDentifier
UWB	Ultra-Wideband
V2V	Vehicle to Vehicle
VHE	Virtual Home Environment
VLR	Visitor Location Register
VOC	Volatile Organic Compounds
VoIP	Voice over IP
VPN	Virtual Private Network
WAE	WAP Application Environment
WAN	Wide Area Network
WAP	Wireless Application Protocol
WCDMA	Wideband CDMA
WDP	WAP Datagram Protocol
WHART	Wireless Highway Addressable Remote Transducer
WiFi	Wireless Fidelity
WiMAX	Worldwide Interoperability for Microwave Access
WLAN	Wireless Local Area Network
WML	Wireless Markup Language
WPAN	Wireless Personal Area Network
WRP	Wireless Routing Protocol
WSN	Wireless Sensor Network

WSP	WAP Session Protocol
WTAI	Wireless Telephone Applications Interface
WTL	WAP Transport Layer
WTLS	WAP Transport Layer Security
XML	Markup Language
ZC	ZigBee Coordinator
ZDO	ZigBee Device Object
ZR	ZigBee Router
ZRP	Zonal Routing Protocol

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