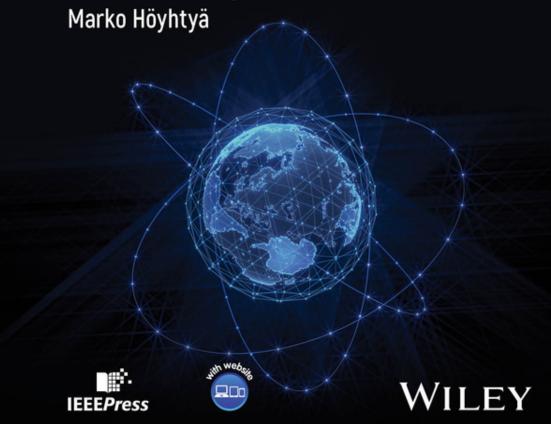
Integration of MTC and Satellites for IoT toward 6G era

Edited by

Hirley Alves

Konstantin Mikhaylov



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Preface

The IoT concept emerged in the 2000s and increased during the last decade. Currently, we are experiencing the deployment of the first IoT applications on a large scale. We foresee that this trend will continue in the coming years. However, much more development and research are needed to cope with the forecasted billions of interconnected devices merged into the Internet in the next decade. Due to the massiveness of the network, current wireless technologies (e.g. LoRaWAN, Cellular-IoT, ZigBee, WiFi, BLE) need to be revised to attend to such demand, even more so concerning energy efficiency and network scalability. This challenge is especially crucial for areas with low population and infrastructure density. Remember that oceans cover a significant share of the Earth's surface, where static infrastructure deployment is exceptionally challenging. Even though it is reasonable to expect lower IoT device density in these regions than in urban environments, where connectivity is well established today, many new applications and services must be deployed in the future to tackle sustainable development goals.

The idea of interconnecting mobile and satellite networks gained much interest from both industry and academia during the past decade, particularly in the cases of coverage extension and backhauling in remote areas. The work has focused chiefly on complementing terrestrial services. This idea has been recently renewed and expanded for seamless IoT integration of mobile and satellite networks. A notable example is directly connecting IoT devices through satellites (direct-to-satellite (DtS)). In addition, the industry (e.g. Iridium, Sateliot, OneWeb, Lacuna Space, and Starlink, to name a few) is continually developing new services to support IoT. Simultaneously, the work on standardization (such as the work actively ongoing within the 3GPP and LoRa alliance) of the DtS is now emerging. Some visions suggest that DtS will become integral to the 6th generation (6G) mobile systems. However, given the novelty of the targeted field and the challenging requirements (e.g. the unprecedented mobility of the low Earth orbit (LEO) satellites, the colossal communication link distances, and the

lack of possibility of servicing the satellites after launch), the integration of IoT and satellite, especially in the context of DtS approach, imposes development of new architectures and technical solutions. Simultaneously, the IoT devices' requirements and traffic patterns differ from conventional satellite terminals today. Another substantial challenge that hampers innovation is the need for more experts in this novel field and relevant textbooks to educate such experts.

This book addresses this challenge by discussing the integration of machine-type communications (MTC) and satellite communication toward 6G. The MTC term emerged during 5G standardization but has grown beyond its original scope. MTC encompasses all (wireless) connectivity solutions and technologies for IoT, including non-cellular ones, e.g. Low-Power Wide Area (LPWA). This book analyzes the drivers, use cases, scenarios, requirements, and architectures of such systems. Besides, we cover the challenges from physical (PHY) to application layers within the detailed and self-sustainable technical chapters. Notably, we review analytical, emulation, and end-to-end simulation tools suitable for the analysis and design of satellite systems. Moreover, we also discuss MTC and satellite integration from the standardization, regulation, and spectrum management points of view. Finally, we analyze and propose new business models and businesses from MTC and satellite integration.

We aim to make the book relevant to students obtaining their first professional degree and the experts who operate in this or adjacent fields and want to revise and update their knowledge or consider changing their focus to this new, promising, and exciting area.

Oulu 14 March 2023 Hirley Alves, Konstantin Mikhaylov, and Marko Höyhtyä

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Acronyms

3D Three-Dimensional

3GPP 3rd Generation Partnership Project

4G Fourth Generation of Broadband Cellular Network Technology
 5G Fifth Generation Standard for Broadband Cellular Networks

5GC 5G Core Network

5GNR Fifth-Generation New Radio

6G Sixth Generation of Cellular Networks

6LoWPAN IPv6 over Low-Power Wireless Personal Area Networks

ACM Adaptive Coding and Modulation

ADR Adaptive Data Rate

AFC Automated Frequency Coordination

AH Authentication Header
AI Artificial Intelligence
AirComp Over-the-Air Computation

AKA Authentication and Key Management

AMF Access and Mobility Function

AMQP Advanced Message Queuing Protocol

ANR Automatic Neighbor Relations

AODV Ad Hoc On-Demand Distance Vector API Application Programming Interface

ARP Address Resolution Protocol ARPU Average Revenue Per User ARQ Automatic Repeat Request

ASTOS Analysis Simulation and Trajectory Optimization Software

AWGN Additive White Gaussian Noise

B2B Business to Business

BER Bit Error Rate

BGP Border Gateway Protocol
BLE Bluetooth Low Energy

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BP Bundle Protocol bps Bits Per Second

BSS Broadcast Satellite Service BTP Basic Transport Protocol

BW Bandwidth

C-V2X Cellular Vehicle-to-Everything
CAGR Compound Annual Growth Rate
CAM Cooperative Awareness Message

CAT Category

CBR Constant Bit Rate

CCSDS Consultative Committee for Space Data Systems

CFO Carrier Frequency Offset CFS Contention-Free Shared

CGC Complementary Ground Component

CHO Conditional HO

CINR Carrier-to-Interference-Plus-Noise Ratio

CIOT Cellular Internet-of-Things CIR Carrier-to-Interference Ratio

CL Clutter Loss cMTC Critical MTC CN Core Network

CNFs Cloud-Native Network Functions
CNN Convolutional Neural Network

CNR Carrier-to-Noise Ratio

Co-IoT Collaborative Internet-of-Things CoAP Constrained Application Protocol

ComSec Communication Security
COTS Commercial Off-the-Shelf

CP Cyclic Prefix

CPU Central Processing Unit

CR Cognitive Radio

CRDSA Contention Resolution Diversity Slotted Aloha

CS Circuit Switched
CSA Coded Slotted ALOHA

CSMA Carrier Sense Multiple Access

CSMA/CA Carrier Sense Multiple Access with Collision Avoidance

CSOC Cybersecurity Operations Centers

CSS Chirp Spread Spectrum
CU Centralized Unit

CU Centralized Unit D2D Device-to-Device

DAMA Demand Assignment Multiple Access