The Handbook of Personal Area Networking Technologies and Protocols

This handbook offers an unparalleled view of wireless personal area networking technologies and their associated protocols. It lifts the lid on their growing adoption within the consumer electronics, home automation, sports, and health and well-being markets.

Bluetooth low energy, ZigBee, EnOcean, and ANT+ are comprehensively covered, along with other WPAN technologies including NFC, Wi-Fi, Bluetooth classic and high speed, and WHDI. It also features 802.11ac, the Internet of Things, Wireless USB, WiGig, and WirelessHD.

The handbook shows how white space radio, cellular, and femtocells have inadvertently blurred the boundaries between personal and wide area communications, creating disruptive topologies through technology convergence. It explores how pervasive WAN technologies have spawned a new generation of consumers through the Lawnmower Man Effect and explains how our personal space has become integral to social media streams, including Twitter, Facebook, and Pinterest.

An essential read for students, software engineers and developers, product planners, technical marketers, and analysts.

Dr. Dean Anthony Gratton is a bestselling author and columnist. Dean has worked extensively within the wireless communications R&D industry and has an accomplished career in software engineering. He was an Editor of the Specification of the Bluetooth System: Profiles, v1.1, and participated in defining the initial Bluetooth Personal Area Networking profiles. He was also active in the NFC technology and marketing committees. Dean is a contributor to several industry periodicals, where he has written many influential articles, sharing his thoughts and challenges on wireless industry news and opinions.
“Once again, Dean demonstrates his knowledge of the wireless standards landscape by providing a comparison of the many different technologies available. This is a valuable starting point for designers trying to unravel the complexities of the wireless world, helping them to determine the best option for their products.”

Nick Hunn, independent consultant
For Sarah, my darling wife and best friend,

“you embody my hope and my immortality”

– D.
“You see, wire telegraph is a kind of a very, very long cat. You pull his tail in New York and his head is meowing in Los Angeles. Do you understand this? And radio operates exactly the same way: you send signals here, they receive them there. The only difference is that there is no cat.”

– Albert Einstein
“The future success of wireless technology rests upon it becoming as overlooked as electricity.”

– Dean Anthony Gratton
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Dr. Dean Anthony Gratton is a bestselling author and columnist. Dean has worked extensively within the wireless communications R&D industry and has an accomplished career in software engineering. He has enjoyed a variety of roles and responsibilities in addition to being an Editor of the Specification of the Bluetooth System: Profiles, v1.1 (the original specification). He has participated in defining the initial Bluetooth Personal Area Networking profiles, and was active in the Near Field Communication (NFC) technology and marketing committees. His wireless research work has been patented.

Dean has developed, architected, and led teams across several new product developments for mobile phones, DigitalTV, Broadband (triple-play), femtocells, Bluetooth, Wi-Fi, ZigBee, NFC, and Private Mobile Radio.

Dean is a Community Editor-in-Chief for Eden (engageSimply.com) as well as being a popular columnist and contributor to a number of industry periodicals, where he has written many contentious articles sharing his thoughts and challenges on wireless industry news, opinions, and gossip. He continues to provide an authoritative published and vocal presence within the wireless communications industry.

Dean has become an influential social media persona (as @grattonboy), with an increasing Twitter following, and has been listed in the 50 “Top Dogs” of Twitter (bullsandbeavers.com). He is also listed as one of the “Top Marketing Book Authors on Twitter” in Social Media Marketing Magazine (smmmagazine.com), and is listed in the “Top 5” Twitter Elite in the United Kingdom, as rated by TweetGrader.com.

Dean holds a BSc (Hons) in Psychology and a Doctorate in Telecommunications.

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Making My Book Social

I have personally embraced social media for several years now and have been very fortunate in garnering some influential clout along the way. As such, I have become an influential social media persona myself as @grattonboy. I’ve been listed in the 50 “Top Dogs” of Twitter and have been regarded as one of the “Top Marketing Book Authors on Twitter” in Social Media Marketing Magazine.

So, I want to make my book social; I mean social in terms of social media. If you like, I want to provide my book with its very own voice and I would like my readers to engage and correspond with my book. Those who are fans of social media will understand the associated benefits and holistically believe in the encouragement of brand awareness and brand identity – after all, it’s consumers like you that define our brands today. You see, social media has inadvertently opened a door. In fact, I dare say it has knocked down walls and barriers that have normally closeted and protected big name brands. It has enabled everyday consumers to engage in two-way communication with them, preventing them from hiding behind the doors of traditional monolog-based promotion and filtering their consumer feedback into fan mail to bolster their corporate egos. What’s more, these same brands can no longer afford a monolog engagement, but instead fundamentally need to embrace engagement with their consumer-base through social media. As consumers, we have become vocal about what we want, and social media has enabled us to engage with the brands that touch and shape our lives – now we are empowered through social media to touch and shape them! I’m introducing my book as a brand with its own identity to encourage engagement and to share thoughts, industry news, and gossip surrounding
the technologies that are featured within. Incidentally, every technology that features in this book also has its very own brand identity on Twitter and Facebook – it’s a perfect platform to engage your audience and build an army of brand ambassadors.

As such, The Handbook of Personal Area Networking Technologies and Protocols has its very own social media presence; after all, my book has an identity, a brand that you can engage with to learn more about its content and where you can discuss in general the technologies that uniquely form the wireless PAN. I’ve created these platforms to
Making My Book Social

offer you every opportunity to engage with me and to learn more about the book. I hope to dispel the rumors and hype that often beset the technology industry.

You can follow @ThePANHandbook via Twitter (see Figure 1) or become a fan of the book via its Facebook Page, facebook.com/ThePANHandbook (see Figure 2). You can even get your daily fix of all things wireless through the book’s very own online newspaper, The PAN Handbook News (courtesy of paper.li), as illustrated in Figure 3.

Finally, you may be a little surprised to see this type of narrative surrounding social media in what is, indeed, a book that is dedicated to the personal area networking space. Well, you’ll be pleasantly surprised to discover more about how our personal area networking space has been drawn into the social media domain later in Chapter 4, “Introducing the Lawnmower Man Effect (LME).”
Crikey, what was I thinking? Another book!

But who am I kidding? I love the challenge that the technology industry provides; I love the volatility, diversity, and inherent freedom of wireless technology. I romance with the notion of what wireless technology can potentially achieve and has achieved; and I just love the crafting process and seeing these pages fall into place – it's simply wonderful. You will soon discover more about my motivation and psyche (verging on madness) when reading the upcoming section “Before We Begin.”

But for now, I like to think that I have written a book that encompasses a healthy review of the wireless personal area networking domain; one which I believe is long overdue. I’ve scanned Amazon and Barnes & Noble and I’m unable to discover similar books. After all, there’s no other book which offers the density of all these technologies in one place – this is by far the most exhaustive coverage yet of the wireless personal area networking space!

Admittedly, I have had some highs and lows during this adventure, and, whilst at the keyboard, I have endured a breadth of emotions, which have been compounded by, on occasions, a need to do something else – damn Twitter! Nevertheless, I’m so pleased that these words have finally reached these pages. My journey hasn’t been lonely – far from it: a large healthy glass of red wine (on occasions too much) has been in proximity whilst I’ve tapped my fingers skillfully across the keyboard listening to Elvis Presley, Neil Diamond and Dusty Springfield, who all made their respective guest appearances, albeit on my Windows Media Player playlist.

I should start by thanking Phil Meyler, Sabine Koch, Sarah Finlay, and Mia Balashova, the Cambridge University Press team, for their incredible patience – yes, it’s taken some time and I have missed several (okay, many) deadlines, and I did manage to see my way through two editorial assistants during my seemingly endless overrun, with Mia being my third! So, so sorry, Phil!

I should also like to thank Nick Hunn and Bruno de Latour for their sanity check mechanisms – a prerequisite when tackling such a technical volume.

As usual, the content that follows has required the support of a number of amazing people and companies without whom this book would have never achieved what it needed to achieve for the wireless personal area networking space. So here goes: the people and companies that have made this short-range RF phenomenon become more than just a dream and, indeed, more than just a seemingly endless number of PowerPoint slides and empty promises.
In true Hollywood style, my guest stars all appear in alphabetical order . . .

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Before We Begin

I’ve been writing books now for over ten years and I entered into this profession completely by accident following a heated discussion with the wife (Sarah). You know how people often say things happen at “the right place at the right time”? Well, for me that’s exactly what happened and how I secured my first book contract with Bluetooth Profiles: The Definitive Guide back in September 2001. The amazement and sheer disbelief that I experienced – “Crikey, I did this!” – and seeing my first book pieced together in a bumper volume inspired me to write and want more. As for the heated discussion with the wife, I’ve been duly advised to save that story for another occasion, perhaps over several glasses of red!

I have historically titled this section of the book the “Preface” – maybe a hangover from my early days of writing. I don’t personally think there’s anything inappropriate with such a title, but I want to start anew by personalizing this section and sharing with you my motivation for writing this book. So, this is where I will now offer you an insight into my psyche and, on occasion, madness. Perhaps I will start by sharing more about me; you know, my specific experience and know-how, and ultimately what qualifies me to write such a book.

Okay. So, my experience spans over 25 years and I’ll keep my account of it here brief! I have worked with networking technologies for around 22 years and have exclusively worked with wireless technology for close to 18. I have worked as a software engineer, developing products first-hand; as a software architect devising unique, creative, and effective methods for enabling networking and wireless technologies, which has led to some designs becoming patented; and I have managed and led teams for a host of consumer electronic products, including mobile phones, DigitalTV, broadband (triple-play), femtocells, Bluetooth, Wi-Fi, ZigBee, NFC, and Private Mobile Radio.

And it’s still an ongoing adventure!

Incidentally, I initially didn’t embark upon a career in software engineering, as my first passion was cooking, although I did dabble with computers and electronics at an early age – at 14, my first computer was an Oric-1 48k! I felt, at the time, that my destiny lay elsewhere, and I started work as a cook at my local Butlins’ Barry Island holiday resort in the Vale of Glamorgan, South Wales, in the hope of following in my grandfather’s footsteps as a culinary wizard. I know what you’re thinking, “Butlins?”, but everyone has to start somewhere, right? Anyway, it all came to an abrupt end and resulted in my first software engineering role, which I still have the fondest memories of. The position was with a small company based in Cardiff, South Wales – a world away from the wireless
communications saga I find myself relishing in today. In the late 1980s and early 1990s I was writing software for the gaming industry; in particular for *Amusement With Payout* (AWP) and *Skill With Payout* (SWP) machines for the United Kingdom, Europe, Africa, and Russia. I was primed to undertake a degree in computer science, but was offered the job on the condition that I withdraw my studies. Okay, so I took the cash! As such, my early career was nothing short of a steep learning curve, as I came to terms with my first software engineering role. But it was a time that was equally so rewarding, as I witnessed some of my crazy notions mature into real products – it was breathtaking. This was also a time sensationalized by Hollywood-like stories, for example when one of my subtle bugs resulted in the Chair of the company being held at gunpoint in Russia – I spent several days sifting through my source code realizing that the fraction of a fraction of a fraction was causing a miscalculation in the jackpot prize that, by the way, occurred over a year! Let’s just say that the Chair escaped unscathed, made a safe return back to base, and was too exhausted and relieved to be angry, much to my relief. Oh, and the excitement over “fake bugs,” known as *Manufactured Malfunctioning Features* (MMFs). It was a craze in the early 1990s to write gaming machines that appeared to be faulty. I would write software that gave the impression to the player that the game was defective, but it was all part of the gambling experience. It seemed like a marvelous idea at the time, but it all backfired, as bars, clubs, and other venues were returning the machines to the operators, as they too saw the games as flawed.

It was such fun.

So, my first engineering role provided me with a sufficient foundation from which I could take on other challenges – I was ready, or so I thought. . . . I was eventually, after five years, wrenched from my role in Cardiff, and from what I considered to be my comfort blanket, kicking and screaming prior to moving to Cambridge, England, with my now wife in the mid1990s. I managed to secure a number of software engineering roles in the Cambridgeshire area, which ultimately led me to some of my most diverse and challenging experiences in technology. But it wasn’t until I secured my role at a North London company in 1999, where I was involved with some of the first Bluetooth products on the market, that my passion and innate belief in wireless technology was seeded. The potential I saw was huge and an enormous leap from the remote control, but fundamental questions needed to be addressed, such as “How should the consumer experience this freedom?” These were questions predominately surrounding the user experience, such as “What should the consumer see at the user interface level?” This had an impact across all consumer electronic products that undertook the wireless theme, and I wanted to encourage a simple, seamless, and transparent experience, especially when there wasn’t an obvious user experience to share, such as for Bluetooth headsets, where you had to rely on a sequence of colored and blinking LEDs to pair and connect.

It proved to be an arduous task then and, unbelievably, it still is today.

Crikey, we took the cable away and introduced a new level of complexity to a product which, for all intents and purposes, worked just as well with a cable. A number of problems emerged as I tried to piece together a simpler and more transparent way of making sure wireless technology delivered on the promises the sales and marketing team
Before We Begin

were spontaneously piecing together – it was a very early stage for wireless technology, and the technology was running even before it could walk.

A time plagued with so much hype.

It was not until 2004, when I received an opportunity to work for a Dutch company based in Leuven, Belgium, where I would become responsible for a breadth of wireless technologies and their introduction to a range of consumer electronic products, that I began truly to comprehend and appreciate the impact of taking away the cable. I was responsible for scoping the software and hardware impact, its feasibility, prototyping, and ultimately the cost of introducing wireless into a number of consumer electronic products. I found myself as a lone ambassador, singing the praises of the potential and opportunity that wireless technology presented. It was primarily my first and uncensored exposure to the wireless PAN space. I was so eager to be one of the first to architect an MP3 player with wireless technology, banishing the routinely cabled headset that traditionally accompanied the products. But my task was fraught with difficulties by an immature wireless technology space and overall poor user experience, which was further compounded by an up-cost in product retail price that was difficult to justify to marketing let alone the end-consumer.

Nowadays, costs have decreased due to the prevalence and acceptance of wireless technology, whereas confidence in the ability of manufacturers to enable consumer electronic products wirelessly has grown. But let’s remind ourselves that the wireless technology journey is ongoing, and that as this technology propagates a wavering path across an unknown troposphere of bureaucracy and mass adoption, all governed by that dreaded price-tag, it has yet to reach its final destination.

I’m guessing at this point that I have unashamedly revealed my maturity and my associated experience with the technology and the industry overall. Admittedly, I now feel old. Anyhow, I write for a number of technology periodicals, which some of you might be familiar with, in which I share my thoughts and opinions about the wireless technology industry. As such, I regularly challenge and tackle issues that need to be shared, but more often faced head-on, so that industry pundits can’t blinker the general consumer into believing features, facts, and figures that may have been tweaked to offer a gloss that isn’t necessarily there (that hype thing again).

In essence, The Handbook of Personal Area Networking Technologies and Protocols is a compilation of my experience of working directly within the wireless communications industry for a wealth of some well-known and steadfast companies from both an engineering and a leadership perspective. By the way, I’m not talking about the fluffy tassels either; I’m talking about the bits, nibbles, and bytes that form the essential software building blocks of some of the most significant wireless products. So yes, I have opened the wireless equivalent of Pandora’s Box; but don’t worry, I have been heavily medicated for your safety.

I chose to write this book to condense the most popular and upcoming technologies and place them all into one volume – a book that would have proved beneficial to me on my technological discovery with wireless technology and one which I’m confident will prove valuable to your own personal journey too, as we all grapple with new wireless experiences. What’s more, I hope to see future editions of this book providing expanded...
information in the existing chapters as well as adding new chapters for the new and
upcoming technologies that (even as I write) are teetering on the edge of being launched
into wireless stardom.

And let’s not forget that whilst I have worked in the industry for a long time, the
personal area network domain is still relatively new, as you will soon discover within
these pages. The wireless technologies that now empower our everyday products are
still evolving and adapting as they, of course, propagate their wavering paths across an
unknown troposphere.

To be continued . . .

– Dean Anthony Gratton
About This Book

Any sufficiently advanced technology is indistinguishable from magic.

– Arthur C. Clarke

I have provided some blurb about my background and experience, and ultimately my motivation, as to why I have written this book in the section entitled “Before We Begin.” So now I want to discuss, in more detail, what I have been up to and what I have actually packed into this gorgeous hardback. I would often write this section at the start of a project with a clear view of what I wanted to achieve, then I would revisit this section at the end of the project to ensure that ultimately I’d achieved what I set out to accomplish.

I’ll be honest with you (intoned with a Welsh twang – just think Rob Brydon), what I often start with doesn’t necessarily end up in the completed manuscript. Until the manuscript is handed over, the book remains a living and breathing document, and so does the table of contents for that matter. I think, as a consequence, it’s a more solidified and stronger end result.

As I have already mentioned elsewhere, the wireless personal area networking domain is relatively new and it’s still an exciting technology sector, as I have personally experienced and am still witnessing. It remains an exciting field of innovation, with manufacturers, engineers, and developers continuing to develop new products in this arena. It’s had a modest lifespan of over a decade or so and has only now started realistically to enable consumers to simplify connectivity between everyday consumer electronic products. Our journey with the short-range RF domain has only just begun (sorry, I didn’t necessarily mean that to sound like a Carpenters’ classic). Anyhow, what I want to say is: wireless technology is still far from perfect, as there are still some idiosyncrasies, wrinkles, if you like, that need ironing out. The Handbook of Personal Area Networking Technologies and Protocols provides an exhaustive reference for the wireless PAN enthusiast and innovator. A reference that will undoubtedly define the foundation from which new wireless product development can be derived and should evolve and adapt.

In essence, the target audience for this book typically comprises individuals from those fields who are continually seeking new perspectives on the subject matter. Moreover, students and professionals who wish to embark upon a career in this enriched domain will seek references that inform them how best to understand, what to expect of, and how to develop applications, products, and services. As such, The Handbook of Personal Area Networking Technologies and Protocols offers the reader a consolidated wealth – a wireless bible of personal area technologies all documented in a single resource.
The book also addresses disruptive topologies through technology convergence, which is a slow but inevitable fate for the personal area domain. Existing/evolving and newer technologies have inadvertently created borderless topologies that engulf the personal area network, such as cellular (3G, 4G – LTE Advanced), white space radio, femtocells, and so on, all providing consumers with every opportunity to connect to an IP-enabled network. You will learn more about what I have penned as the Lawnmower Man Effect (LME) later in Chapter 4, “Introducing the Lawnmower Man Effect,” a term that classifies the ability afforded to a new generation of consumers who seek to have a permanent connection to anything, anytime, anywhere. Essentially, we are witnessing a rapid development of new products and services which have diversified the market sector. The telecommunications industry continually offers a breadth of services and products for consumers who wish to remain connected, irrespective of location.

So, The Handbook of Personal Area Networking Technologies and Protocols has been structured into four parts or sections, and in Part I, “What’s In Your Area Network?,” I provide a close-up view of the personal area space and explore what a personal area network is. I look at how disruptive topologies through technology convergence
are diversifying our everyday ability to remain connected despite our location. I also introduce the Lawnmower Man Effect, which explains how, as consumers, we can nowadays traverse digital systems all captained from our personal networking space.

In Part II, “The Wireless Sensor Network,” I showcase the wealth of low power and sensor technologies that will ultimately shape and define how technology is used within homes, industry, and commercial buildings. The notion of a “smart home,” now referenced today as home/building automation, or domotics, has been used for more than thirty years and only today are we witnessing mass adoption. Nowadays, in an increasingly eco-conscious society, we need to understand better the consequences of the long-term impact of our relentless consumption of limited energy resources. I review the overall energy impact of consumer electronic products and look at several techniques and initiatives that help and encourage manufacturers to provide greener products.

As we move to Part III, “The Classic Personal Area Network,” I review the most common and well-known technologies that we have taken for granted and commonly associate with wireless connectivity. Firstly, I look to unravel the basic ingredients of the PAN space whilst delving deeper into the wireless technologies that have shaped what I have coined the “classic technologies.” In this section we review in hardcore detail a