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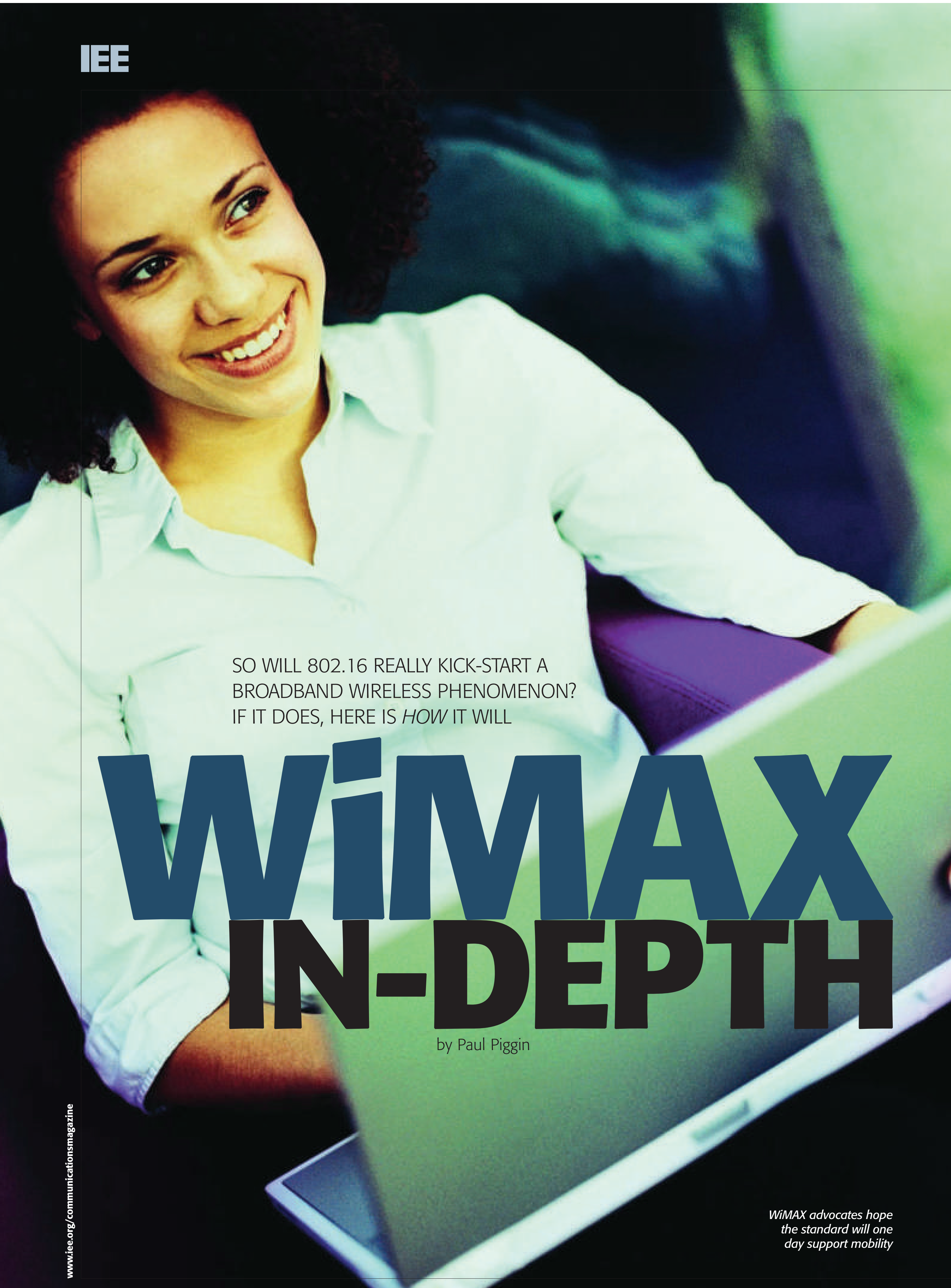

SO WILL 802.16 REALLY KICK-START A BROADBAND WIRELESS PHENOMENON? IF IT DOES, HERE IS *HOW* IT WILL

WiMAX IN-DEPTH

by Paul Piggin

WiMAX advocates hope the standard will one day support mobility

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By demonstrating a long history of latent expectation, fixed wireless may be considered to have underperformed. Previous market forecasts have implied that the golden era for fixed wireless access was almost upon us – we are still waiting.

This is undoubtedly due, in part, to a bewildering array of companies and proprietary air interfaces, coupled with conflicting arguments on the most effective way to deliver services over the air. This predicament ensures scepticism in the marketplace and confusion for operators.

Enter IEEE802.16, an emerging air-interface standard providing last-mile broadband wireless access. Will this provide the tonic to shake up fixed wireless? This unifying standard – fundamentally different from IEEE802.11 and Wi-Fi – brings the promise that companies will see a return on investment and benefit from the long-awaited hope of equipment interoperability. Although it has been widely reported that 802.16-compliant equipment is capable of data rates of up to 70Mbit/s over distances of up to 50km, what is needed at this stage is to take a step back from the hype of recent months and carefully examine the inner structure of the standard and its real possibilities.

THE ROUTE TO STANDARDISATION

The standard itself was borne from existing fixed wireless companies driving the standardisation process within the IEEE. These firms are currently expending significant effort ensuring they contribute to the development of the standard. As a consequence, many companies previously competing to sell their proprietary solutions are uniting under the banner of IEEE802.16. Several new entrants, not traditionally associated with wireless access networks, have also been heavily involved in the process.

As with 802.11 and Wi-Fi, 802.16 has industry representation in the form of the WiMAX (worldwide interoperability for microwave access) forum. The stated aim of this organisation to "facilitate the deployment of broadband wireless networks based on the 802.16 standard by helping to ensure the compatibility and interoperability of broadband wireless access equipment".

ETSI in Europe has been working on a similar standard within the BRAN (broadband radio access network) project. It has developed the HiperACCESS standard for frequencies above 11GHz and the HiperMAN standard for frequencies below 11GHz. Although HiperACCESS is less well aligned, HiperMAN has evolved over a protracted standardising process to be a subset of 802.16 and is supported by WiMAX, thereby allowing interoperability across US and Europe. The ITU is ratifying the standard for worldwide use (together with HiperMAN/HiperACCESS) through the development of a specific recommendation identifying broadband wireless access standards.

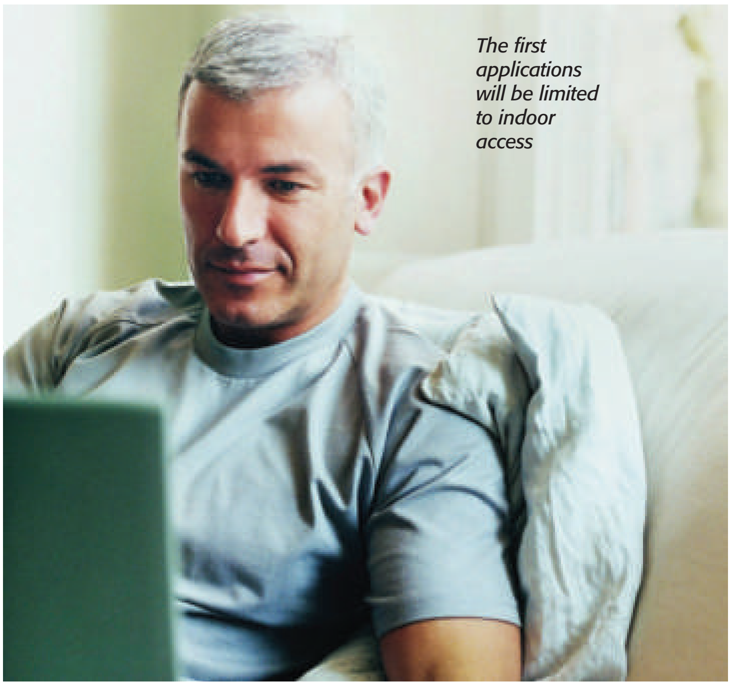
The air interface standard IEEE802.16-2004 was undergoing the last reviewing stages before publication at the end of July 2004. Meanwhile, activity is still ongoing in defining an amendment to the standard that will allow mobile broadband wireless access at vehicular speeds. Interoperability between the mobile and fixed system is mandated. This work, known as 802.16e, is due for completion in March 2005.

AN OVERVIEW OF THE STANDARD

IEEE802.16 defines the WirelessMAN air interface for wireless metropolitan access networks (MANs). Specifically, the standard defines a common MAC (media access control) layer and a number of PHY (physical) layers, i.e. layers 1 and 2 of the ISO 7 layer model. The standard was initially defined to cover the frequency range from 10 to 66GHz – a range that included spectrum for licensed broadband wireless access, for example LMDS (local multi-point distribution system).

With application to SOHO (small office/home office) and larger environments, raw data rates in excess of 120Mbit/s are quoted. Latterly the standard has been extended to cover frequencies in the range below 11GHz with the addition of the 802.16a project in March 2000. These two specifications were subsequently integrated into a single standard, again called 802.16.

The frequency range 10-66GHz supports a line-of-sight single carrier (SC) PHY, while below 11GHz both SC and multiple carrier (MC) PHY modes for non-line-of-sight applications are supported. These are: SCa (term for SC below 11GHz), OFDM (256FFT) and OFDMA (2048FFT). All PHYs support higher order modulation schemes up to →



The first applications will be limited to indoor access

> QoS mapping is provided in the upper part of the MAC, which exemplifies a fundamental distinction from the contended MAC nature of Wi-Fi systems


WiMAX hotspot coverage is a distinct possibility

64-QAM (256-QAM for the SC PHY). The PHY configurations are shown in table 1.

The standard recognises the emergence of unlicensed spectrum in the 5-6GHz band, defined by CEPT (Europe) and U-NII (US). This designation is referred to as WirelessHUMAN (high-speed unlicensed MAN) and is covered by the three lower frequency PHYs. Additional MAC functionality is mandated in this mode supporting DFS (dynamic frequency selection). DFS is required to avoid 'primary users' and co-channel interferers (such as Wi-Fi devices) in shared spectrum. The term primary user is likely to mean co-channel or adjacent channel military radar. Although the interference profiles and detection mechanisms are different for the two types of interference, the standard provides MAC message support for both scenarios. To further mitigate interference, other restrictions such as a channel plan and limitations on transmit spectral mask are included.

IEEE802.16 offers a flexible burst-type frame structure with fixed frame duration. Duplexing is provided by means of either TDD (time division duplex) or FDD (frequency division duplex). Support for half duplex FDD (H-FDD) SS (subscriber stations – the term for terminal equipment in the standard) is also provided. H-FDD SSs are those that transmit and receive on different frequencies but not at the same time – hence reducing complexity and cost. The TDD frame structure is shown in fig 1. It is interesting to note the adaptive subframe boundary in TDD whereby allocation of downlink and uplink resources can be carefully controlled, which is ideal for asymmetric services.

Each downlink subframe begins with a broadcast synchronisation preamble and a broadcast FCH (frame control header) containing control information destined for all SSs. Depending on the PHY the downlink can be configured for TDM, TDMA or a combination of both; the uplink is TDMA with a preamble transmitted ahead of each SS's transmission. Each TDM/TDMA burst carries MAC PDU containing SS data. The beginning of the uplink subframe provides contention slots for initial ranging and bandwidth requests. Respectively, this provides a facility for entry of new users into the network and provides a fast reaction mechanism for bandwidth requests from an SS.

A set of MAC management messages is defined within the standard. The messages defining the sub-division of a frame are noteworthy as they are treated differently with regards to their transmitted position in the frame. The messages – DL-MAP, UL-MAP, DCD and UCD – are broadcast in or immediately after the FCH (depending on how this is defined by a particular PHY), ensuring they can be decoded by all SSs.

DL-MAP (downlink-MAP) and UL-MAP (uplink-MAP) MAC messages define the location of the downlink and uplink bursts. DCD (downlink coding descriptor) and UCD (uplink coding descriptor) MAC messages define the PHY characteristics on the downlink and uplink bursts, such as modulation scheme and coding. The generalised downlink and uplink subframe structures for all PHYs are shown in figs 2 and 3.

The MAC (currently specifying ATM and packet higher layer interfaces) is connection-oriented, with links between the BS (basestation) and SS uniquely identified by a 16bit CID (connection identifier). This provides support for QoS (quality of service) via service flows, whereby QoS mapping in the form of classification of higher layer data is provided in the upper part of the MAC. In this regard, the standard exemplifies a fundamental distinction from the contended MAC nature of Wi-Fi systems as defined by 802.11.

In addition to PMP (point to multi-point), there is a mesh mode originally championed by Nokia. This is supported for the OFDM PHY using TDD. It is expected that the mesh mode be used with omni-directional antennas. However, a directed mesh (DM) configuration, proposed by Radiant Networks, is also available by means of configuring the PMP mode, providing PtP (point-to-point) links on which a directional mesh can be built.

The MAC for the lower frequency PHYs supports additional options. These are: AAS (adaptive antenna system), STC (space time coding), and ARQ (automatic repeat request). AAS provides increases in range and system capacity, using antenna beam steering. This technique increases spectral efficiency by electronically directing antennas and minimising inter-cell interference. The support mechanisms for AAS allow for a mixture of AAS and non-AAS users covered by the same BS. STC provides transmit diversity using two antennas at the base station. Diversity gain is provided by virtue of two independently fading radio channels combined at the single SS antenna. ARQ provides reliable data transfer at the MAC layer. Failure of data reception is signalled to the sender and transmission is repeated.

The standard also suggests: network entry and synchronisation procedures; scope for link adaption (adaptive modulation and coding); a security sublayer; system profiles for use with PICS (pro forma interface conformance statement) and companion documents detailing conformance tests and coexistence in licensed bands.

WHAT DOES THE FUTURE HOLD?

Comment and analysis of WiMAX in the technical press have been intense, and even general-interest outlets such as the BBC website have been alerting a wider audience about an imminent wireless revolution. Reports over the past six months have detailed numerous alliances between companies to drive forward WiMAX developments. Expectations of equipment availability reportedly range from late 2004 to the first half of 2005, so it won't be long before reality can be compared with expectation.

Companies may choose to specialise in terminal or infrastructure development, chipset solutions, reference designs or provide system solutions – the cost-benefits that this may attract are obvious. The potential applications for WiMAX are also diverse:

- Infill broadband coverage for areas that DSL cannot reach – primarily rural areas
- Provide hotspot coverage (similar to Wi-Fi but over wider areas)
- Contiguous broadband cellular coverage
- Flexible backhaul or targeted high bandwidth to large customers

The WiMAX certification process specifies the use of a subset of the MAC and PHY configuration parameters – restricting the range of possibilities for system configuration and providing a route for equipment interoperability. The configuration specified under the WiMAX Forum harmonises the 802.16 and HiperMAN PHYs by using OFDM. Within the IEEE the standard is still evolving with task groups being created to provide specific enhancements.

Will WiMAX provide the catalyst that will see broadband wireless realise its potential? Time will tell; but if the early signs are correct, we may see WiMAX being as widely accepted as Wi-Fi. Perhaps the surviving companies providing fixed wireless can forge a standard that will allow interoperability, provide for volume manufacture, reduce cost, influence spectrum availability and draw a line under a troubled past. ■

Designation	Frequency range	Duplex
WirelessMAN-SC	10-66GHz licensed bands	TDD/FDD
WirelessMAN-SCa	< 11GHz licensed bands	TDD/FDD
WirelessMAN-OFDM	< 11GHz licensed bands	TDD/FDD
WirelessMAN-OFDMA	< 11GHz licensed bands	TDD/FDD
WirelessHUMAN	< 11GHz licence-exempt bands	TDD

Table 1: IEEE802.16 air interface configurations

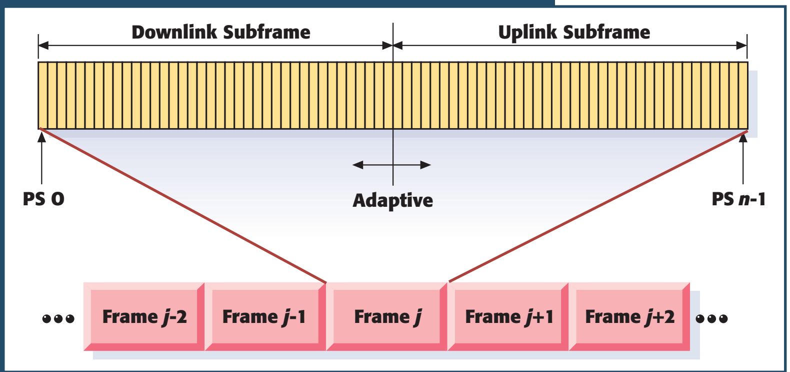


Fig 1: IEEE802.16 TDD frame structure

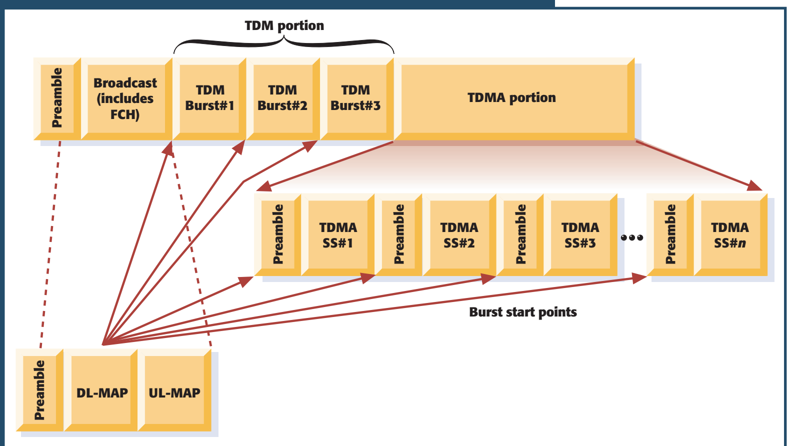


Fig 2: Downlink subframe structure

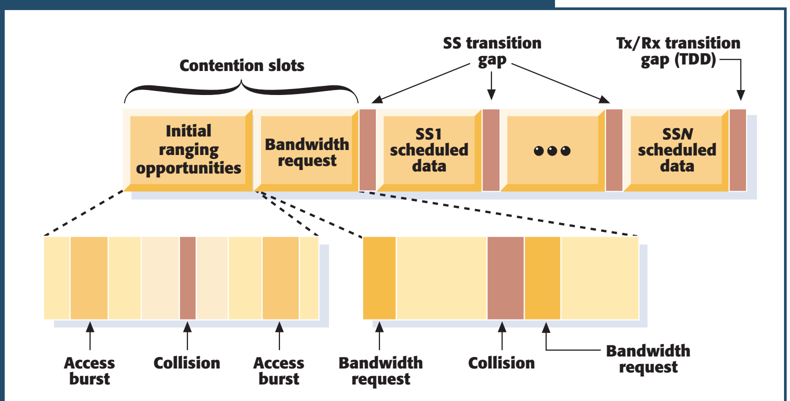


Fig 3: Uplink subframe structure

Dr Paul Piggin is a senior systems engineer with Cygnus Multimedia Communications. **He would like to acknowledge the valuable support of Barry Lewis of Redline Communications in the preparation of this article. Parts of the text include excerpts reprinted with permission from IEEE Std P802.16-REVd/D5-2004 ('Draft IEEE Standard for Local and metropolitan area networks Part 16: Air Interface for Fixed Broadband Wireless Access Systems')**