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Re:	Response to the call for comments on the 16m system evaluation methodology
Abstract	This submission motivates the inclusion of outdoor-to-indoor as well as pure indoor environments into the system evaluation methodology of 16m. We demonstrate the economic importance of both types of environments. We furthermore show that several important propagation parameters show fundamentally different behavior in those environments compared to pure outdoor environments.
Purpose	[Description of what *specific* action is requested of the 802.16 Working Group or subgroup.]
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On the importance of indoor environments for IEEE 802.16m systems

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1. Introduction and Motivation

In the IEEE 802.16m standardization, there is a current discussion about the choice of testing environments. While three environments, namely suburban macrocell, urban macrocell, and urban microcell, have already been accepted, there is an ongoing discussion about the need for two further scenarios, namely outdoor-to-indoor, and pure indoor environments. The current document is intended to help in this discussion.

Two key questions must be answered in order to arrive at a reasoned decision:

1. are indoor and outdoor-to-indoor scenarios relevant deployment scenarios, i.e., do they occur significantly often to motivate a detailed study?
2. are their features (propagation channel, user speed, etc.) significantly different from other, already accepted scenarios. By "significantly different" we mean, e.g., "could a system proposal that is the best in an outdoor scenario become second-best (or worse) in an indoor scenario?

As we will describe in greater detail below, our answers to the questions are:

1. indoor and outdoor-to-indoor scenarios are both of great economical importance. As a matter of fact, we anticipate that the majority of all data traffic of 16m will occur in such scenarios.
2. indoor and outdoor-to-indoor scenarios show many differences to pure outdoor scenarios. The differences include (i) user mobility (low or nonexistent for indoor users), (ii) steeper capacity distributions, (iii) higher attenuation of the signals from transmitter to receiver. (iv) different importance of the LOS component, (v) large angular spread at indoor base stations, making sectorization difficult, and thus posing new challenges for base station design and signal processing.

The remainder of the contribution is organized the following way: Section 2 describes the differences in the propagation scenarios, including mobility and channel characteristics, of indoor and outdoor-to-indoor environments versus outdoor environments. Section 3 gives an overview from an economic and service provider point of view for the coverage of indoor environments. Section 4 presents the summary and conclusions.

2. Outdoor-to-Indoor scenarios

An outdoor-to-indoor propagation occurs when the base station is located in an outdoor environment, typically on a mast or rooftop (in the case of a macrocell), or on a lamppost etc. (in the case of a microcell), while the mobile station is located inside a building. It must be recognized that such a scenario has significantly different propagation characteristics from an outdoor scenario, where the MS is located at street level either in the hand of a user, or on a car.

2.1 Why is an indoor user different?

In this section, we discuss the key differences between an indoor and an outdoor mobile station.

A major difference lies in the mobility of the users. While outdoor users are moving fast (with a 25% of the users moving with 30 km/h), indoor users are essentially stationary. Users are either completely static (e.g., when using a laptop with 16m capability) or move with at most 3 km/h. The user stationarity can be an advantage (since it reduces the necessary overhead for link adaptation etc.) and/or a drawback (because little temporal diversity is available).

Another important set of differences lies in the propagation channel. In general, indoor environments show a higher elevation spread at the mobile station (due to the presence of a ceiling as well as a floor). There are also major differences in delay spread, cross-polarization, etc. Since those issues depend on the exact type of the environment (indoor vs. outdoor-to-indoor), they will be discussed separately in the following subsections.

2.2 Outdoor-to-indoor

The fundamental propagation processes can be approximately factored into two processes: (i) a propagation from the base station to the outside of the building in which the MS is located, and (ii)propagation from the building walls/windows to the mobile station. Considering the building wall-windows as an "effective" (distributed) antenna, we can thus anticipated the following properties:

1. The angular spread at the BS is similar to the angular spread in an outdoor scenario (e.g., urban micro)
2. The delay spread is the sum of the delay spread of an outdoor and an indoor environment. Since the delay spread in an outdoor environment is typically larger than in an indoor environment, the total delay spread is – to a *very* rough approximation – equal to the outdoor delay spread.
3. An extra attenuation due to the walls of the buildings. It must be stressed that the attenuation is greatly dependent on the angle of arrival of the incoming waves.
4. The cross-polarization discrimination is determined by both the outdoor and indoor environments.

The combination of MIMO propagation properties (low angular spread at BS, high angular spread at MS) results in an environment with overall characteristics that are different from any other environment.

It is a widespread assumption that the outdoor-to-indoor scenario can be modeled as an outdoor scenario with an extra pathloss. While this assumption holds for the received fieldstrength and (approximately) for the delay spread, it is *not* valid for the angular and polarization properties of the channel. Firstly, the attenuation of each propagation path depends on the angle of incidence; secondly, the AoA is usually determined by reflections on indoor walls near the MS. Therefore simulations for 16m (which will use MIMO) cannot use the same approximations that second- and third generation system simulations used.

A comparison of the proposed model parameters for urban microcell and outdoor-to-indoor shows that

1. outdoor-to-indoor has zero LOS probability, while urban microcell has appreciable LOS
2. the mean angle-of-arrival spread (57 degrees) is almost doubled in the outdoor-to-indoor environment

compared even to microcell NLOS (35 degrees) and more than doubled compared to microcell LOS (25 degrees).
3. the XPR spread is much larger in the outdoor-to-indoor environment (12 dB vs. 3 dB in urban microcell). This has important consequences for systems with polarization diversity.

2.3 Pure indoor scenario

In this section, we point out the major differences between the indoor and the urban microcell environments. We can anticipate marked differences, since the propagation mechanisms are different (e.g., through-wall propagation is important indoors, while it is mostly irrelevant in microcells). This conjecture is confirmed by an inspection of the WINNER parameters for the different environments, where we find the following results:
1. smaller delay spread (25ns vs, 75 ns in the NLOS case) and different shape of the power delay profile
2. much larger angular spread at the base station (60 vs. 15 ns mean angular spread in the NLOS scenario; 43 vs. 3 degrees in the LOS scenario)
3. The shadow fading variance is much higher in the indoor case. (6 dB vs. 4 dB in the NLOS case).
4. Further simulations have shown that the sensitivity of the capacity to the antenna patterns (e.g., cell sectorization) is markedly different for indoor and microcellular cases.
5. the pathloss coefficient is much higher in the NLOS case (3.7 vs. a maximum of 2.8)

3. Economic importance of indoor deployments

Both the indoor and the outdoor-to-indoor scenarios aim at describing the situation where a user is located inside the building, i.e., they represent different ways of providing indoor coverage.

It is difficult to overstate the importance of indoor coverage.. Users have become accustomed to ubiquitous service, and will not accept a network that does not offer good indoor coverage. In Japan and Europe, the majority of all voice calls is placed from (or is addressed to) a user inside a building. The indoor usage will certainly increase in the future, due to the following trends:
1. there is an accelerating trend for users to completely discard their landlines in favor of wireless-only service. This trend was first observed in Scandinavia in the late 1990s, and has become worldwide in the meantime..
2. data traffic is very often generated by users that are inside buildings. In particular, users with laptops are usually located inside a building. This fact can be easily understood from the following: (i) data terminals cannot be operated by people driving cars, (ii) in bright sunlight, it is difficult to read LCD screens, (iii) in many areas, inclement weather makes prolonged outdoor websurfing impractical during most of the year.
3. new price structures (flat fees) encourage the use of cellphones as modems; also new laptop models offer long-range data services.

For this reason, we anticipate that data traffic with indoor mobile stations will drastically increase in the future. Following the ITU market forecast, the user density for high-rate and very-high rate traffic in dense urban environments will show the highest increase (compared to other environments), from 2010 to 2020, see table 1. Even more importantly, the percentage of indoor users in dense urban environments is more than 60%

(currently, 30% of all users are at home, 30% at the office, and 40% in public spaces).

Speech	Dense urban	Urban	Suburban	Rural
2010	147,840	60,300	8,190	1,560
2015	185,300	81,600	13,440	3,180
2020	219,830	97,440	18,090	4,130
LowRate	**Dense urban**	**Urban**	**Suburban**	**Rural**
2010	45,836	18,695	2,539	484
2015	131,218	57,784	9,517	2,252
2020	174,011	77,131	14,320	3,269
Medium rate	**Dense urban**	**Urban**	**Suburban**	**Rural**
2010	9,570	3,904	530	101
2015	70,612	31,095	5,122	1,212
2020	126,835	56,220	10,437	2,383
High rate	**Dense urban**	**Urban**	**Suburban**	**Rural**
2010	1,836	749	102	19
2015	20,315	8,946	1,473	349
2020	83,078	36,825	6,837	1,561
Very high rate	**Dense urban**	**Urban**	**Suburban**	**Rural**
2010	148	60	8	2
2015	2,553	1,124	185	44
2020	26,989	11,963	2,221	507
Ultra/Super rate	**Dense urban**	**Urban**	**Suburban**	**Rural**
2010	-	-	-	-
2015	371	163	27	6
2020	5,809	2,575	478	109

Table 1 User density in different environments [ITU-R]

Another important question is whether indoor environments can be covered by outdoor base stations, or whether indoor base stations have to be added. In our view, the answer to this question depends on the environment:

1. in suburban scenarios with a sparse building structure, coverage by outdoor base stations will usually sufficient. The buildings in which the mobile stations are located are small, and the outer walls usually not made from sturdy material (Japan uses light building materials because of earthquake risks; much of the US uses wood; Europe uses brick).
2. in metropolitan environments, especially in large office buildings, satisfactory coverage by outdoor base stations is not possible. This fact, which we have observed repeatedly in our own network, can be explained by a number of facts:
    a) the outer walls of many office buildings are steel-and-concrete constructions, with a consequently large attenuation for all incident radiation. In Europe, the user of metal-covered energy-saving windows compounds these effects.
    b) the dimensions of the office buildings are much large than those of residential buildings. This makes it more difficult for waves to penetrate into the center of the building.
    c) the requirements for coverage and network reliability are higher for professional users (which inhabit office buildings) than for residential buildings.

Another important question is whether indoor coverage by 802.16m base stations is necessary, or can be replaced by 802.11 networks. In our view, 802.11 networks cannot replace 802.16 coverage, for the following reasons:

1. 802.11 operates in an unlicensed band. Thus, no guarantee for the quality of service can be provided by the network operators. While the 802.11e standard is an important step towards QoS, it still has to rely on the availability of spectrum in a certain environment. Operating in an unlicensed band, such an availability cannot be guaranteed.
2. It is difficult to achieve very high data rates with 802.11, even with the 802.11n standard that is currently being developed. 802.11n requires an SINR of more than 30 dB to achieve its maximum possible data rate.
3. Our experience is that a larger number wants a seamless coverage by the same system that also provides the outdoor services. The “seamlessness” of the handover is currently not satisfactory for many customers.

For all these reasons, we think that indoor base stations will be an essential part of 16m deployments.

4. Summary and conclusions

In this document, we have analyzed the importance of testing 16m system proposals in outdoor-to-indoor and pure indoor environments. We showed that outdoor-to-indoor propagation environments already now have critical importance for cellular operators. Furthermore, in the future, the use of indoor base stations for Wimax and 16m networks will greatly increase. This effect is due to changing user habits, limited quality-of-service of alternate indoor coverage methods, and the requirement of seamless and reliable coverage of indoor environments.

We have further demonstrated that the operating conditions, including traffic patterns, user mobility, and propagation channels, show considerable differences between indoor and outdoor environments. Thus, it is *not* sufficient to test 16m system proposals in outdoor environments only. Rather, we have to make sure that the proposed systems are the best ones in both outdoor and indoor environments.

Given these facts, we advocate the inclusion of the outdoor-to-indoor and pure indoor environments in the system evaluation methodology. In particular, the current document supports comment number ?

References:

[ITU-R] International Telecommunications Union, “IMT Market Forecast”, 2007.