A Classification Scheme for Wireless Channel Models Across the Development Life Cycle

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***Abstract*— Wireless channel models play a critical role at all stages of the development life cycle, from standards development to network deployment. Because most organized efforts to develop channel models are relatively short term and are designed mostly to support concept assessment and standards development, the distinctive needs and requirements for the channel models used at each stage of the cycle are rarely acknowledged. Here, based upon consideration of the needs and requirements for channel models across the product life cycle, we propose that such models be divided into three distinct types (I, II and III) based upon their role, generality, application, computational complexity, primary stake holders and time available to develop. We further propose that channel model development road maps be created that will allow developers concerned with particular wireless technologies and/or deployment scenarios to more effectively communicate their needs channel modelers.**

***Keywords*— channel model, propagation, development life cycle.**

I. Introduction

Most organized efforts to develop wireless channel models have been relatively short term and designed mostly to support concept assessment and standards development. However, the channel models used at each stage of the development life cycle have distinctive needs and requirements that are rarely acknowledged by the channel modelling community. This has often led to challenges within the developer community as channel models suitable for use at a particular stage may not be available.

Here, we propose that such models be divided into three distinct types based upon their role, generality, application, computational complexity, primary stake holders and time available to develop. We conclude that development of universal channel models that are suitable for all phases of the development life cycle is likely not achievable and that a federation of models which are consistent but not identical is a more appropriate goal. Accordingly, we further propose that developers concerned with particular wireless technologies and/or deployment scenarios create channel model development road maps in order to more effectively communicate their needs to channel modelers [1].

II. Channel Modelling & the Development Life Cycle

The development life cycle consists of multiple stages. During the conceptual design stage, standards development and systems engineering phases, channel models are generally incorporated into software-based simulation tools that are used to determine how well the system design is capable of mitigating channel impairments and delivering the required performance. During the implementation, integration and test, and manufacturing phases, channel models are generally incorporated into hardware-based simulation tools that are used to determine how well implementations of the system design perform in practice. During the deployment and operational phases, planning tools are used to guide the decisions required to bring the system into successful operation and to diagnose and correct problems in the field.

The need for higher-level, simpler channel models for the deployment and operation phase was called out in [2]. Consideration of the needs and requirements for channel models across the product life cycle reveals that they can naturally be divided into three distinct types based upon their role, generality, application, computational complexity, primary stake holders and time available to develop, as suggested by Fig. 1. We propose the following model types:

Type I Channel Models support conceptual design, standards development and systems engineering. They are *site general* in nature, *i.e.,* they are broadly applicable to a class of environment rather than specific to particular building layouts and terrain. Their main role is to support *fair comparison* between alternative link-level concepts, *i.e.*, they support prediction of relative rather than absolute performance. The comparisons are generally made between results obtained through simulation. Because they support work conducted at the very earliest stages of the product life cycle, the time available to develop such models is limited. The channel modeling committees associated with standards groups are often expected to develop or recommend such models in as little as 18 months. Because such models are usually quite simple, computational complexity is generally not an issue.

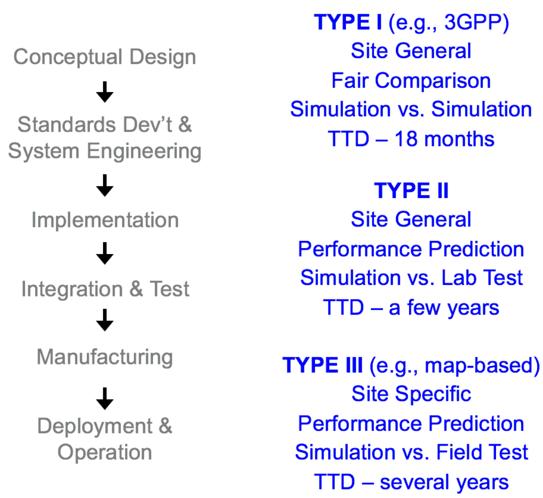

Fig. 1. Types of channel models applicable throughout the product life cycle.

Type II Channel Models support implementation, integration & test and manufacturing. They are still site general in nature, but their main role is to support *performance prediction* given that the results obtained through simulation will be compared directly to results obtained through lab- or field-based testing. Because they support work conducted at the mid-point of the product life cycle, the time available to develop such models is a little more generous and may be as long as a few years. However, few organized efforts to develop such channel models exist. In many cases, Type I models are pressed into service but with mixed results given their limited accuracy.

Type III Channel Models support large-scale network deployment and operations. They are generally *site-specific* in nature, *i.e.,* they are specific to particular building layouts and terrain and are generally map-based. As with Type II models, their main role is to support performance prediction given that the results obtained through simulation will be compared directly to results obtained through lab- or field-based testing. Because simulations conducted with such models may involve hundreds, thousands or even more links, significant efforts are made to minimize computational complexity. Because they support work conducted at later stages in the product life cycle, the time available to develop such models is even more generous and may be as long as several years. However, few organized efforts to develop such channel models exist.

While the three types of models described above may be differentiated on technical grounds, they may also be differentiated by their primary stakeholders. Standards Development Organizations (SDOs) and the groups that contribute to conceptual design and standards development are the primary stakeholders for Type I models. Equipment developers and manufacturers are the primary stakeholders for Type II models. Planning tool developers and network operators are the primary stakeholders for Type III models. The interests of spectrum regulators tend to evolve over the product life cycle, and range from a need for basic Type I models in the early stages of spectrum policy development, to a requirement for predictive, Type II and III models supporting coexistence and interference studies during the later stages.

III. Implications for Channel Model Development

Ideally, the trends and patterns uncovered by channel models will reveal, or at least inform, effective and efficient strategies for mitigating channel impairments. Such models will allow developers to confidently assess the merits of alternative design options and tradeoffs in meeting both performance and business goals.

As mathematical models, channel models are abstract and simplified constructs that describe a part of reality and which are created for a particular purpose. An effective channel model cannot simultaneously maximize generality, realism and precision. As wireless physical layers have become more complex, they have become more susceptible to an increasing range of channel impairments and distortion mechanisms. However, not all physical layers are susceptible to the same impairments. Technology specific channel models will have common elements, but will generally be simpler and more tractable than the long sought after but likely unattainable universal channel model.

Considering the vast differences between the model types described above, and the key differences between different radio access technologies, we conclude that the development of universal channel models that are suitable for all phases of the product life cycle is likely not achievable. Instead, we propose that a *federation of channel models* which are consistent but not necessarily identical seems to be a more appropriate goal.

We further propose that developers create channel model development road maps that both reflect the above and communicates the needs of the developer and the regulatory/International Telecommunications Union (ITU) communities to the channel modeling community. Such roadmaps are generally developed through a consultative process in which stakeholders and researchers in a given sector collaborate to assess and compare the current state of the art to future needs.

Effective channel model development roadmaps will aid both researchers and institutions in their activities by prioritizing research that will best deliver both incremental and disruptive improvements in technology and process. Such road maps have proven to be enormously valuable in a variety of sectors ranging from microelectronics to health research, and it seems likely that such a road map will be useful here provided that it fully addresses the manner in which channel modelling needs and requirements evolve across the product life cycle.

References

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