DIGITAL TWINS IN MOBILE NETWORKS

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Wireless Infrastructure Association
2111 Wilson Blvd., Suite 210
Arlington, VA 22201

wia.org

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INTRODUCTION

While the concept of digital twins is not new, the importance of digital twins has been realized only in the past few years. A digital twin is an accurate and detailed software model of a physical asset that mimics its behavior. In wireless networks, the digital twin is a representation of the physical wireless network, including the tower assets, physical network components and the associated data center functionality.

Digital-twin models can be used in both carrier and private enterprise networks, including the physical infrastructure, such as fiber conduits, towers, small cells and power systems. The digital twin also can be used to monitor network operations and predict events that may lower network performance. Testing and validation of new components, architectures, solutions for network problems and new software loads can be done using the digital twin, reducing the risk to the physical network. A digital twin also can offer one central view of the network that multiple design tools access, instead of having multiple data sets of the same network, increasing consistency and accuracy.

The more accurate the digital model, the higher the degree of accuracy in predicting, testing and validating the configuration or policies of the network. When better data is collected, the digital twin will better emulate the actual network.

Data for a digital twin is collected from:

- Individual component specifications and performance;
- The physical network layout;
- Network analyzers;
- Engineering drawings and schematics; and
- Drones and 3D imagery.

There is a role for artificial intelligence (AI) in network digital twins, although there is confusion about the relationship between a digital twin and an artificial intelligence model. AI and digital twins are not the same thing, but AI algorithms can be used to create a digital-twin model, as well as the ongoing analysis and decision-making.

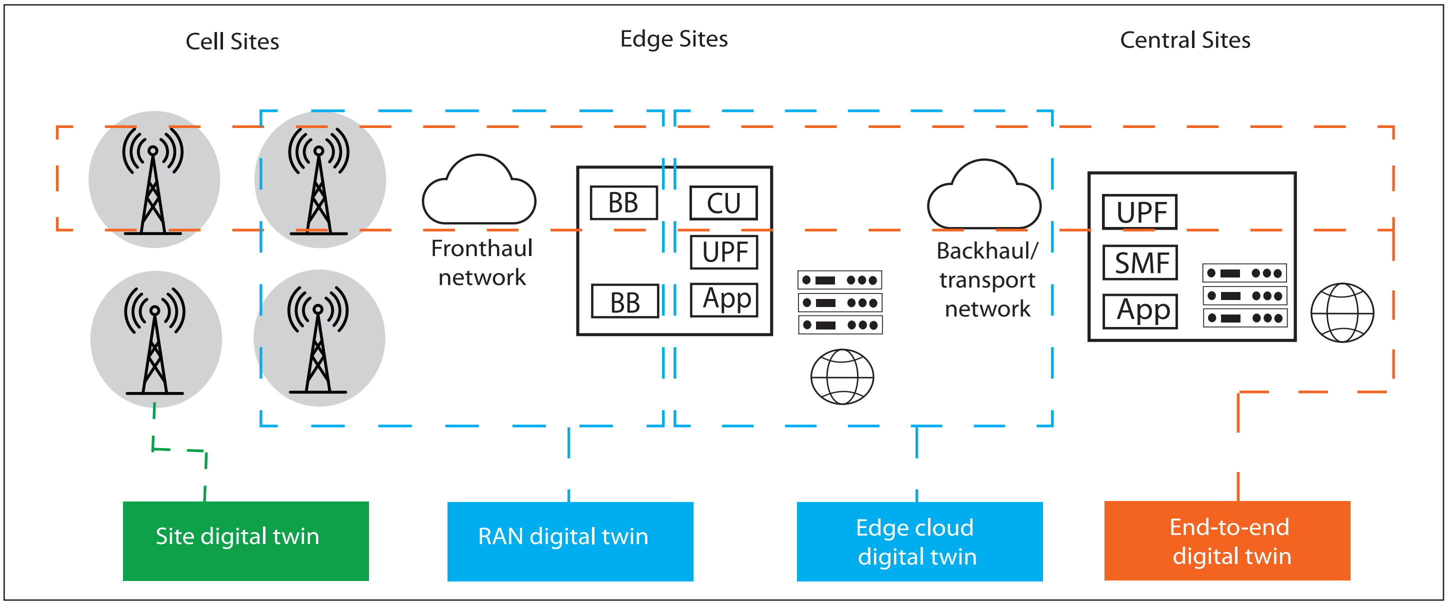
What is a digital twin?

A digital twin is simply a model of a physical asset or infrastructure that can be used to test potential changes or policies of the asset, emulating performance of the real-world asset. In telecom, a network digital twin models each component across the network and data center, giving a realistic digital representation of the entire network. For a wireless network, the model would include digital representations of the antennas, radios, fiber connections, routers and core network, plus all the connections and physical assets, including towers, mounting hardware, cabling and connectors.

It is important for the digital-twin model to be synchronized with the production network so that any changes in the live physical network are also emulated accurately in the digital model.

Digital twins are not unique to telecom networks. Digital twins have been used in civil engineering, aeronautics, automotive design and manufacturing, and a range of other industries to emulate complex systems. However, digital twins are a relatively new concept for 4G and 5G networks.

Figure 1: Areas of interest for digital twins in mobile networks.



Source: Ericsson white paper ‘The future of digital twins’, 2023

How is a digital twin used?

Carriers can use a digital twin to monitor network operations and predict events that may lower network performance. Possible solutions to network problems can be tested on the digital twin to assess their effectiveness before being deployed in the live network.

A digital twin also can offer one central view of the network that multiple design tools access, rather than having multiple data sets of the same network. This allows all engineering, design and management tools to use the same data source for consistency and increased accuracy.

As networks increase in complexity, with more software-based functions and components, the need for digital twins increases. Testing network updates and changes, software patches, security policies and configurations all can be done in an accurate digital-twin emulation of the physical network. Once validated, the changes can be implemented without risk to the uptime of the physical network.

Possible solutions to network problems can be tested on the digital twin to assess their effectiveness before being deployed in the live network.

How is a digital twin built?

As with most data models, a digital twin of a wireless network is only as good as the information collected from the real-world, live network. The higher the accuracy of the data collected, the more representative the digital-twin emulation will be.

Data for a digital twin is collected from:

- Specifications and performance of the network components, such as radios, antennas and routers;
- Physical descriptions of the network components and layout;
- Network analyzers showing the performance of the radio network in real-time;
- Engineering drawings and designs;
- Drones and 3D digital images of physical sites and connections.

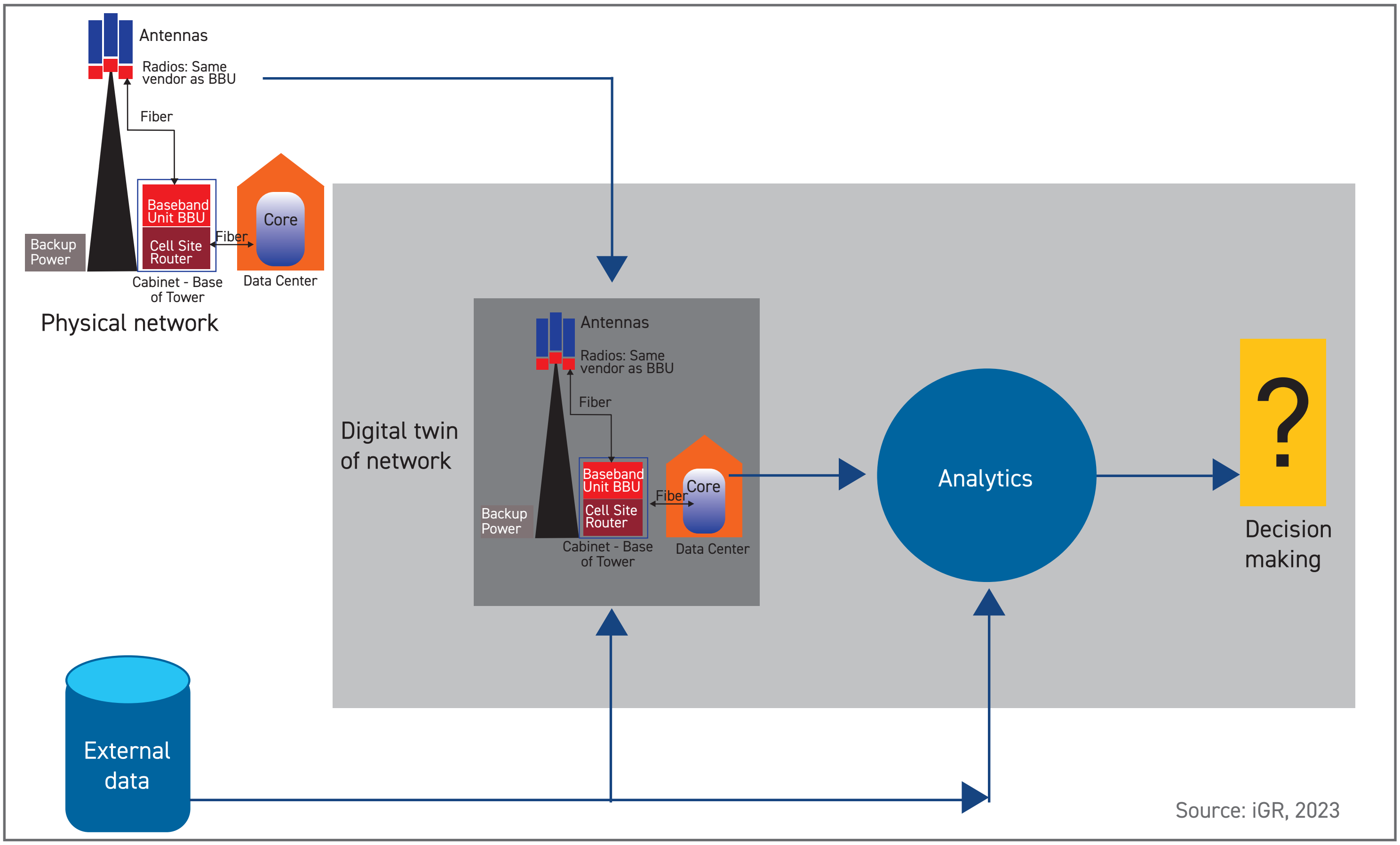
Data from these sources is combined into the digital-twin model, which is then updated as the physical network changes. For example, real-time network performance data is analyzed and used to update the digital twin to keep the model as current as possible.

As wireless networks become more complex, the importance of digital twins in network design, deployment, testing and operations increases. A comprehensive network digital twin models each component across the entire network and data center giving a realistic digital representation of the entire network. For a wireless network, the model would include digital representations of the antennas, radios, fiber connections, routers and core network, plus all the connections and physical assets, including towers, mounting hardware, cabling and connectors.

It is important that the digital-twin model be synchronized with the production network, so that any changes in the live physical network are also emulated accurately in the digital model.

The chart on the next page shows the main parts of the digital-twin system (in grey). Data from the physical network and external data sources (network performance data; 3D images; drone data, etc.) is used to build the initial twin model and keep it updated. Analytics systems use the digital-twin model to aid in decision-making as needed.

Figure 2: Digital-twin system inputs and functions



Source: iGR, 2023

The digital-twin model can be used to emulate all parts of the physical network including:

- 4G/5G radio and channel;
- 4G eNodeB and 5G gNodeB functionality such as mobility control and handoff, data transfer, session management, positioning and functional splits between the Distributed Unit (DU) and the Centralized Unit (CU);
- Fronthaul functionality and protocols such as evolved Common Public Radio Interface (eCPRI);
- Functional disaggregation and distribution between the core network and the edge;
- Network slicing;
- Traffic flow to and from multiple devices and device types; and
- Security threat analysis to test and audit vulnerabilities and risks.

Engineering vs. inspection accuracy

One important distinction in the data used to create a digital twin is accuracy. Generally, the higher the resolution of the images or scans, the higher the accuracy of the resulting model. For “engineering class” models that have accuracy down to a few millimeters, high-definition images may be required. But lower-resolution images can be used to build an accurate digital twin model.

However, higher-resolution images mean a larger data file, which may be difficult to transmit from the field. In addition, the equipment used to capture high-definition images is more expensive than using lower-resolution, real-life images to build the model.

The following images show the general difference between real-life images from a drone (on the right) and the subsequent 3D model (on the left).

While the real-life image from the drone includes the background and is extremely detailed, the 3D model includes all the engineering details of the RAN and the equipment, but without the background.

Figure 3: Comparison of 3D model vs. drone/360 real life images

Source: Neptuno/SiteSee 2024

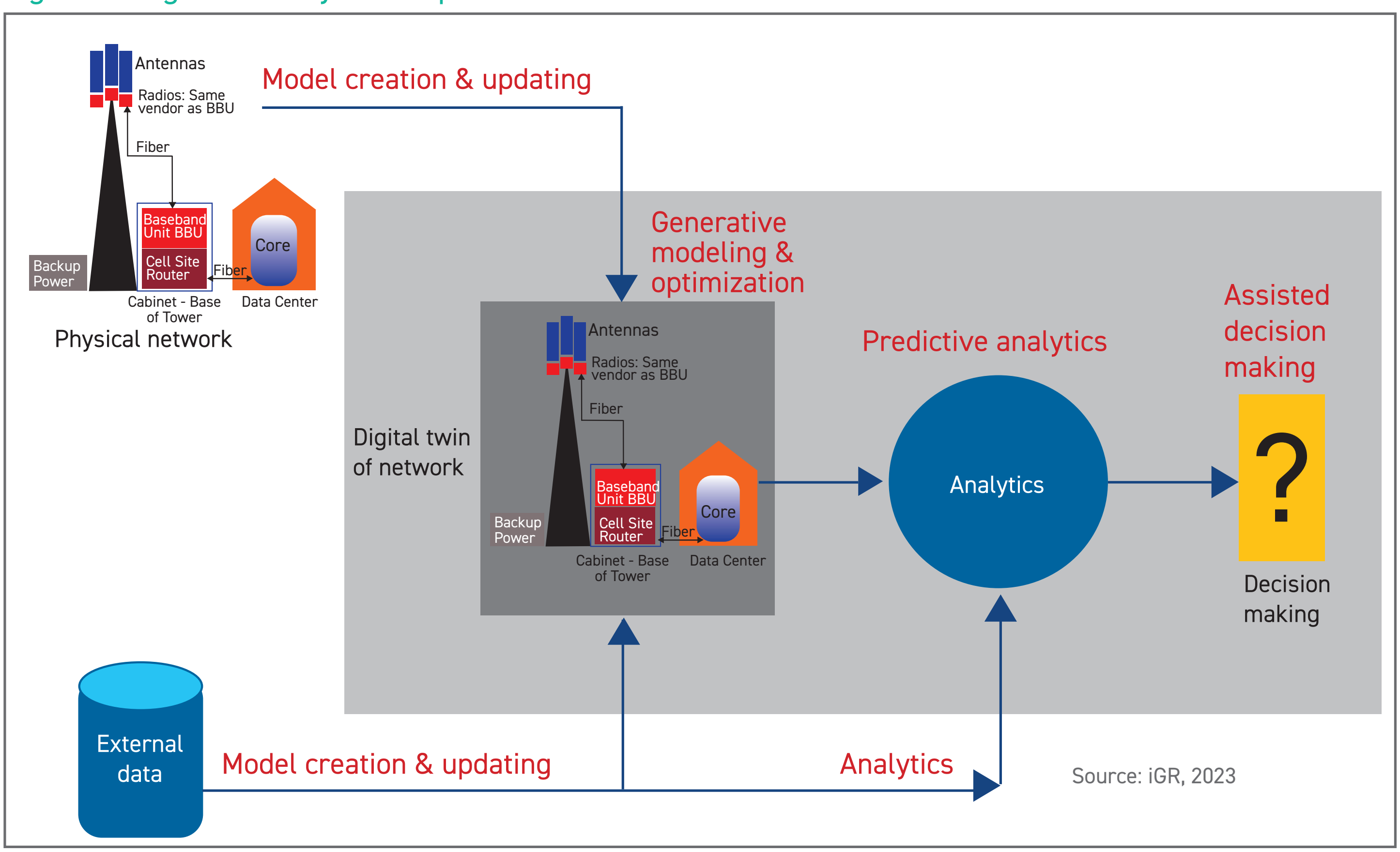
How does AI play into digital twins?

Digital-twin models are not AI models. But AI algorithms can be used to create a digital-twin model, as well as ongoing analysis and ultimately decision-making.

The following chart shows the network digital-twin model and the steps where AI can be applied (in red):

- Model creation and updating: AI is used in the initial steps to create the model, such as in the analysis of digital images or including component specifications. Once the model is built, updates can be analyzed using AI and incorporated into the model.
- Generative modeling and optimization: using data from the physical network and external data sources, the initial model is built using generative AI techniques.
- Predictive analytics: using the digital-twin network model, the AI algorithm can assist in the analytics phase of the process, including predicting component failures or suggesting maintenance schedules, among other functions.
- Decision-making: the final step in the process is to make decisions about what actions need to be taken in the physical network. AI can assist and make recommendations.

Figure 4: Digital-twin system inputs and functions



Source: iGR, 2023

The benefits and considerations of a digital twin

There are multiple benefits to developing and using a network digital-twin model in addition to things to consider before using one.

Benefits

- Reduce the cost and time to deliver network changes and manage network assets, including the ability to test and validate network changes before deployment.
- Reduce the risk of network failures and the resulting liability, including reducing network configuration errors.
- Enable uninterrupted testing at any time, including the ability to develop new test cases and scenarios without risk to the physical network.
- Visualize and track physical changes in the network and at the component level.
- Combine separate data sources and inputs into a single merged environment that shows the current network status.
- Ability to predict future network conditions for inspections, reporting, and analysis.
- Reduce cost and implementation time for physical cell site upgrades and changes, including deployment of a new RAN.
- Improved training outcomes using the network digital twin.
- Ability to use machine learning (ML) and AI algorithms on a single accurate network model to increase analytics and insights into network operation and deployment changes.

Things to Consider

- Amount and cost of the compute and memory resources required to accurately model the physical network.
- Defining a clear business case that justifies the necessary investment.
- There are no industry standards for defining the digital twin data structures and models.
- How to overcome staff inexperience with digital models to establish trust for the model or its outcomes.
- Building digital-twin models and the resulting test cases and scenarios may require new skill sets from current IT resources.
- The complexity of building and maintaining an accurate multivendor network digital-twin model, including the challenge of getting the required component-level data.

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