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A TRANSDISCIPLINARY FRAMEWORK FOR 5G AND FUTURE NETWORKS ENABLED APPLICATIONS AND SERVICES INDUSTRY CONNECTION

5G ENABLED AGRICULTURE ECOSYSTEM:

FOOD SUPPLY CHAIN, RURAL DEVELOPMENT, AND CLIMATE RESILIENCY

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ACKNOWLEDGMENTS

Special thanks are given to the following reviewers of this paper:

Purva Rajkotia, IEEE

Rosalinda Saravia, IEEE

IEEE SA Transdisciplinary Framework for 5G and Future Networks Enabled Applications and Services Industry Connections (IC) Working Group

The Institute of Electrical and Electronics Engineers, Inc. 3 Park Avenue, New York, NY 10016-5997, USA

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PDF: STDVA25897 978-1-5044-9360-4

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5G ENABLED AGRICULTURE ECOSYSTEM:

FOOD SUPPLY CHAIN, RURAL DEVELOPMENT, AND CLIMATE RESILIENCY

ABSTRACT

Agriculture plays an important role in feeding the global population, fostering rural development initiatives, and reducing the overall global carbon footprint for climate resiliency. Furthermore, the agriculture ecosystem spans many industries both urban and nonurban across the globe.

The IEEE SA Transdisciplinary Framework for 5G and Future Networks Enabled Applications and Services Industry Connections (IC) white paper discusses the end-to-end agriculture ecosystem in the context of the food supply chain, rural development, and climate resiliency. A transdisciplinary framework that includes ecosystems, networks, and governance may address the end-to-end agriculture ecosystem in a sustainable and systematic manner. The food supply chain includes the natural environment and resources, food production, processing and packaging, distribution, and consumption. Rural development is discussed within the context of connectivity, cross-ecosystem touchpoints, and local economic development. Climate resiliency is addressed through changes in land use and land cover (LULC).

Numerous opportunities and challenges may be addressed in a phased approach that caters to local priorities, capabilities, and constraints. The transdisciplinary approach facilitates collaboration across different stakeholder groups that strive toward comprehensive solution development across the end-to-end agriculture ecosystem. Potential opportunities include technology innovations, standards development, access to services, economic development, policy development, and resource management.

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Keywords: 5G, 6G, agriculture, climate resiliency, connected farm, ecosystems, environment, farming, fishing, food supply chain, governance, indigenous, IoT, land cover, land use, networks, precision agriculture, ranching, rural development, transdisciplinary framework

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1. EXECUTIVE SUMMARY

The IEEE SA Transdisciplinary Framework for 5G and Future Networks Enabled Applications and Services Industry Connections (IC) white paper is based on earlier work from the IEEE Future Networks Initiative (FNI) Integrated Network Generations Roadmap (INGR) Applications and Services Working Group [2], [19]. The Transdisciplinary Framework IC intends to engage diverse stakeholder groups to develop actionable frameworks that integrate ecosystems, networks, and governance functions. Stakeholders with a business, technical, or government background may be engaged through a sustainable structured framework that may be used to realize complex functions. This white paper addresses the agriculture ecosystem and its relationships with the food supply chain, rural development, and climate resiliency.

Agriculture may also be viewed as a hub of activities that lead to smart communities. A transdisciplinary framework highlights the food supply chain through specific ecosystem stages or industries that address natural resources, food production, processing and packaging, food distribution, and consumption and recycling. Fixed and mobile terrestrial and non-terrestrial networks may provide the essential communications capabilities through access, service delivery, user and operations management, and relevant network extension components across the ecosystem stages. Connectivity and accessibility [8] are essential access component drivers for rural and remote communities to improve access to services and local gross domestic product (GDP) growth. A strategic rural development vision can be developed through stakeholder engagement and described in comprehensive plans or strategic plans that specifically address local priorities, capabilities, and constraints. Climate resiliency may also be addressed through land use and land cover (LULC) changes during regulatory and policy development. The white paper describes the agriculture landscape with a focus on food supply chain, rural development, and climate resiliency through a sustainable structured transdisciplinary framework that is flexible, scalable, and repeatable. Several opportunities are described that may be addressed in separate initiatives.

2. TRANSDISCIPLINARY FRAMEWORK

The transdisciplinary approach engages diverse disciplines across business, technology, and governance functions. Applications and services across academia, industry, and government are aligned through integrated ecosystems, networks, and governance functions. Each ecosystem stage represents industry group(s) that offer similar products or services. Figure 1 highlights five distinct areas in the agriculture ecosystem that

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include food production resources, food production, processing and packaging, food distribution, and consumption and recycling. Additional stages may be defined, as needed, to meet the needs of an evolving industry landscape and related industry life-cycle changes within the agriculture ecosystem.

Each ecosystem stage or industry group is aligned within and across different ecosystems and ecosystem stages through key communication network components and technology enablers. The fixed and mobile terrestrial and non-terrestrial network components include access, service delivery, user management and network operations, and network extension functions. Governance approaches include strategic, tactical, and operational functional alignments to meet the local priorities, capabilities, and constraints.

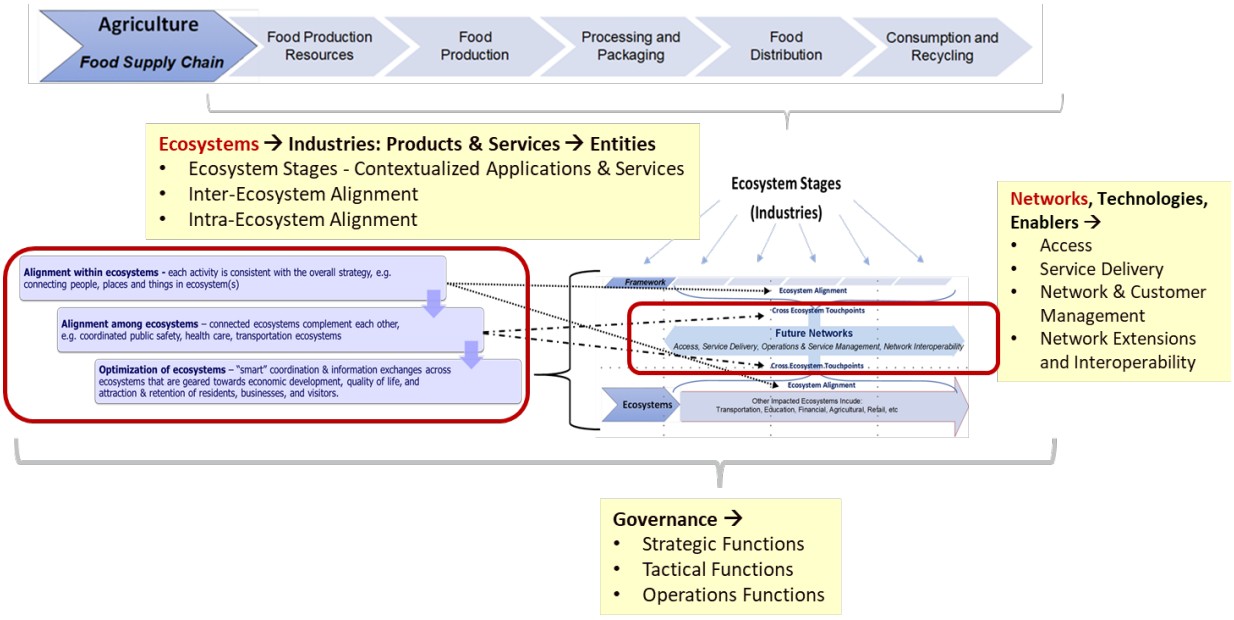


FIGURE 1 – Transdisciplinary approach to the agriculture ecosystem

Agriculture ecosystem stages and cross-ecosystem touchpoints alignments address risks and opportunities across the food supply chain, rural development, and climate resiliency. Agriculture integration with urban and rural communities through the transdisciplinary framework shown in Figure 2 aligns the following:

- **Ecosystem of ecosystems**—Contextualized applications and services within and across ecosystems
- **Network of networks**—Technological convergence and seamless interoperability across terrestrial and non-terrestrial networks
- **Governance function of functions**—Coordinated strategic, tactical, and operations functions

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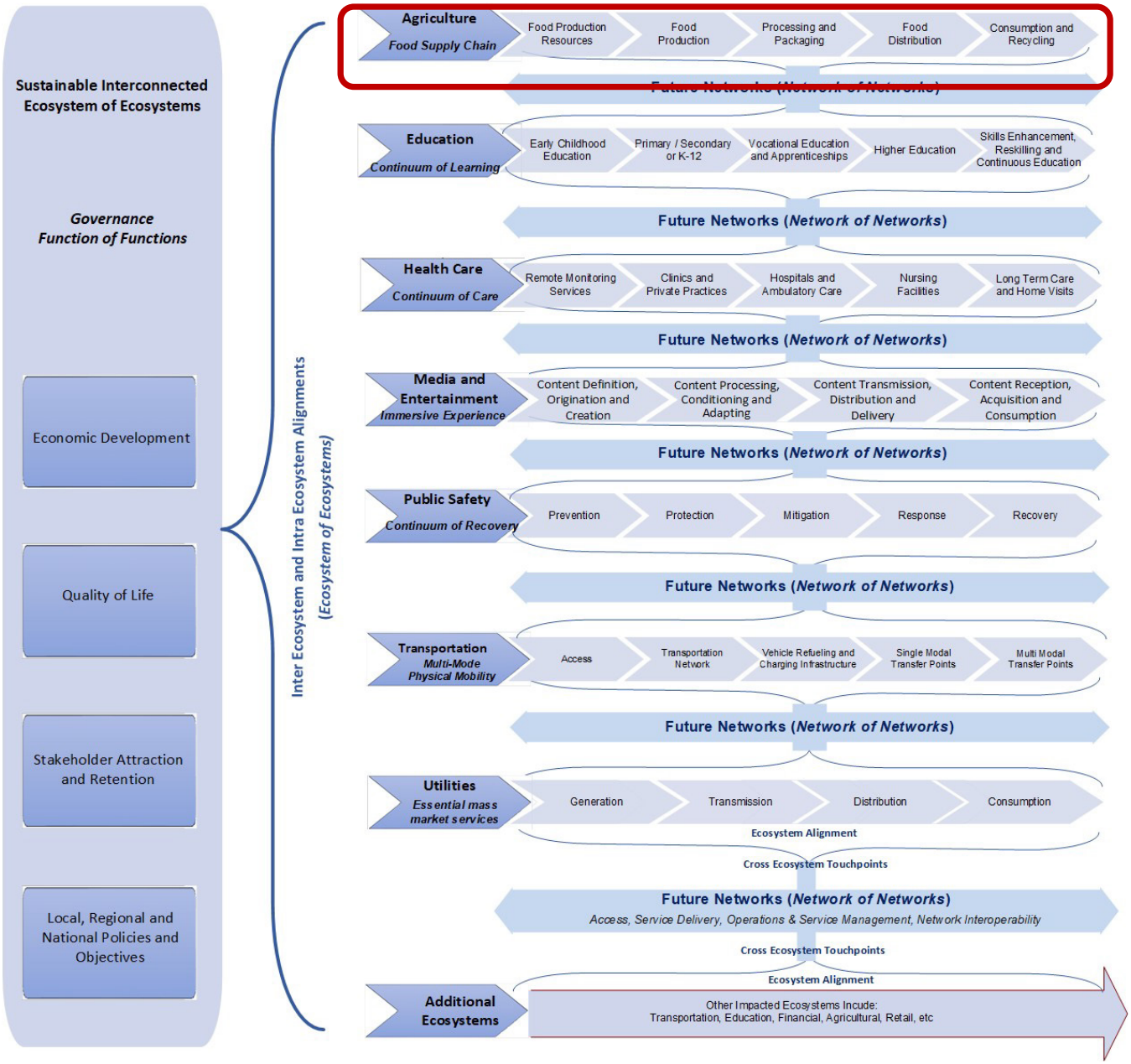


FIGURE 2 – Transdisciplinary framework [2]

The transdisciplinary framework is a sustainable, structured, flexible, repeatable, and scalable framework that can be customized to meet local priorities, capabilities, and constraints. This framework facilitates the systematic discovery of risks and opportunities that include development of new standards, products, or services. Furthermore, this framework can be used to address other ecosystems, such as the healthcare continuum of care [20], technologies for specific public safety mission areas [18], and smart cities [21], for different localized priorities, capabilities, and constraints [24].

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2.1. ECOSYSTEM OF ECOSYSTEMS

The ecosystem of ecosystems perspective uses contextualized applications and services and strategic alignments among intra-ecosystem, inter-ecosystem, and optimized ecosystem functions to optimize local capabilities and constraints for specific operational or mission-specific objectives. This approach includes the following:

- **Alignment among the agriculture ecosystem stages**—Each ecosystem stage may be viewed as an industry or a set of industries that provides similar products or services across the agriculture supply chain. End-to-end ecosystem information visibility may be enabled.
- **Alignment among agriculture and other ecosystems—**Ecosystems with aligned stages may regularly overlap and impact other ecosystems, for example, electrified connected vehicles. Therefore, challenges and opportunities arise to identify and address cross-ecosystem touchpoints.
- **Optimization of ecosystems—**Ecosystem stages are combined at their *current operational state* to fulfill specific objectives that may include economic development, quality of life, stakeholder attraction and retention, and area-specific objectives.

The ecosystem and cross-ecosystem stage alignments are shown in Figure 3.

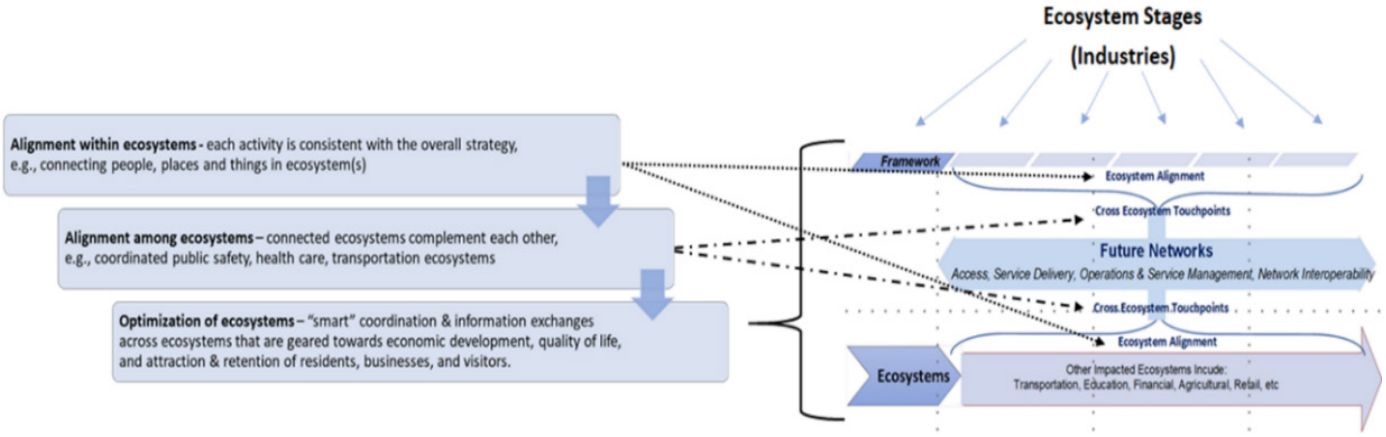


FIGURE 3 – Ecosystem and cross-ecosystem stage alignments

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2.2. NETWORK OF NETWORKS

Terrestrial and non-terrestrial networks are generalized into key components as shown in Figure 4 and include the following:

- **Access, for example, radio access network (RAN)**—Ability for a user or "thing" to access the network
- **Service delivery, for example, edge or core network**—Service delivery to/from the user or "thing"
- **Network operations and customer management, for example, business/operations support system (BSS/OSS)**—Customer management and network operations
- **Network extensions, for example, roaming**—Network interoperability with other networks

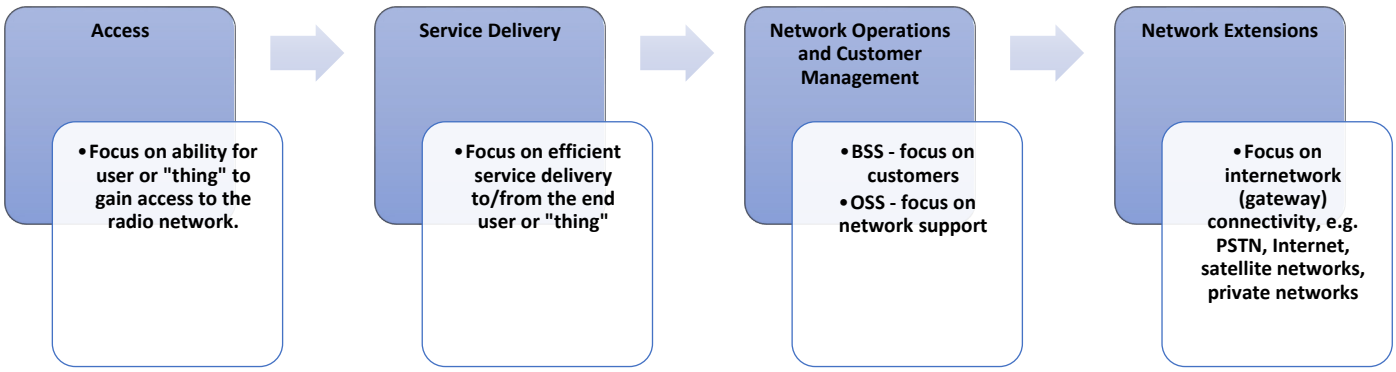


FIGURE 4 – Key network components for fixed and mobile terrestrial and non-terrestrial networks

2.3. GOVERNANCE FUNCTION OF FUNCTIONS

Governance functions are used for complex coordination in which contextualized end-to-end information visibility is essential across the multiple connected supply chains. The governance function of functions approach includes the following combined strategic, tactical, and operations perspectives:

- **Strategic functions**—Includes long-term capabilities planning, strategic positioning within a competitive landscape, and policy development activities

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- **Tactical functions**—Includes targeted functions to respond to planned and unplanned events such as pandemics, natural and human-made disasters, large crowds, and so on
- **Operations functions**—Includes information flow for end-to-end visibility and intra-ecosystem and inter-ecosystems necessary for normal operations

3. AGRICULTURE ECOSYSTEM AND STAGES

The agriculture ecosystem is uniquely positioned to address the food supply chain, rural development, and climate resiliency in a coordinated manner using the transdisciplinary framework.

3.1. FOOD SUPPLY CHAIN

The food supply chain extends across the five ecosystem stages: food production resources, food production, processing and packaging, food distribution, and consumption and recycling. Farming, ranching, and fishing are essential activities for the food supply chain. 5G and future networks play a pivotal role in addressing opportunities and challenges in improving food production. For example, the Ohio State University precision agriculture Terra project found that a single 100-acre corn field can generate up to 60.2 TB of data with 2,475 files using 39 different file types through the normal course of growing their crop in an approximate 110-day cycle. A 100-acre field would generate approximately 60 PB of data, which is more storage than 466,000 iPhones and three times more than the amount of data Google processes in a day [28].

5G and future networks promise to enhance the efficiency of the food supply chain through improved yield rates and services. Findings from the FCC Precision Ag Task Force [11] highlight the following areas for improvement:

- Yield gaps from lost crops are based on weather and management decisions.
- Data may be used earlier in the process to improve logistics and tactical decision-making.
- Interoperability challenges include the following:
    - Complex stakeholder groups, for example, farmers, original equipment manufacturers, suppliers (seed, chemicals), service providers, consultants, government agencies, and software/analytics companies.
    - Private and public networks, data, and cloud/edge platforms.
    - Lack of adequate standards.

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