IEEE Future NETWORKS

Enabling 5G and Beyond

International Network Generations Roadmap (INGR) Virtual Workshop

Energy Efficiency WG

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IEEE

In Memoriam

6G Summit 2020

There Is Not Enough Electricity to Run 5G - Finding the Road to 6G

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0:00 / 21:17 TU Delft 1 ERIDAN

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Motivations

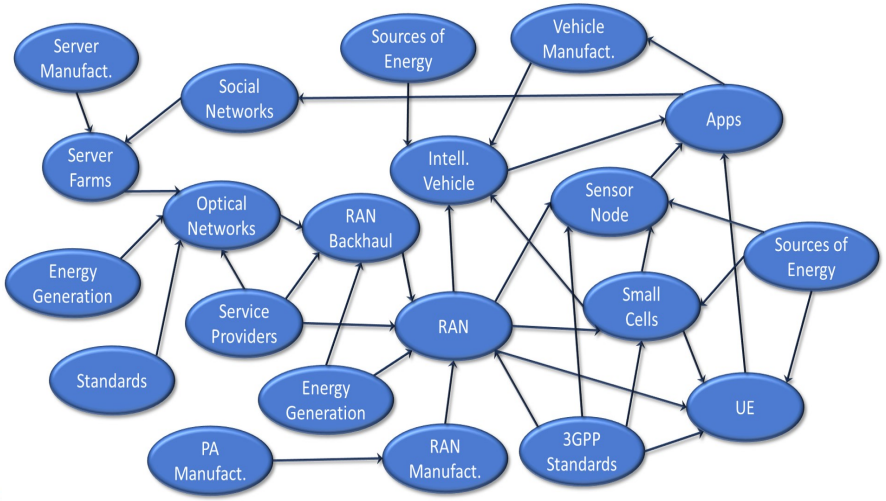
- Today's existing (and proposed) 5G deployments are at-risk of being non-sustainable from both technical and economic perspectives.
- Lack of consistency across ecosystem stakeholders, particularly with focus on Energy Efficiency.
- Energy Efficiency determines the success of any application and its viability on a global scale.
- Concern that global deployment will not be equitably executed from a socioeconomic perspective.

10-year Vision

- Energy consumption seen as the “currency” that determines business viability, as it fundamentally impacts both CAPEX and OPEX.
- Linkage of HW/SW hooks enabling self-optimization at all points of the network.
- Universal availability of EE-centric tools/processes/models/standards applied across the ecosystem and global infrastructure.
- Utilization of System-level Metrics (technical & financial) to drive stakeholders’ decisions, so that:
  - All technologies are optimally leveraged (Energy Provisioning and Harvesting, Radio and Network Infrastructure, Data Processing, Storage and Distribution)
  - Benefits are achieved (Cost-effective and Equitable Availability of Services, and Sustainable Infrastructure and Business Models)

Today's Landscape

- Diverse, Heterogeneous Players Contribute To The Ecosystem
- Different Business Models And Incentives
  - Payback Model Uncertainty/Risk?
  - Poor Linkage to Socioeconomic Impacts (The Unconnected)
- Siloed Technology Development
- No Shared Metrics



Scope

- The EE WG is committed to education on energy-related issues/concerns/opportunities across all industry stakeholders.
- From HW configuration to SW architecture, everything impacts power consumption, often in a poorly understood way.
- The Roadmap Chapter on Energy Efficiency will cover:
  - Analysis of current technology trajectories at-risk of leading to unsustainable outcomes.
  - New Metrics that enable assessing and optimizing energy consumption from system- to grid-level and socioeconomic impact.
  - Technologies that can overcome the risk of the "Energy Gap" (from Energy Harvesting and Radio architectures at the Edge to Computational structures and AI in the Network, and Energy Storage and distribution).
  - Opportunities to Improve Sustainability and "Connecting the Unconnected"

Challenges and solutions for 10-year Vision

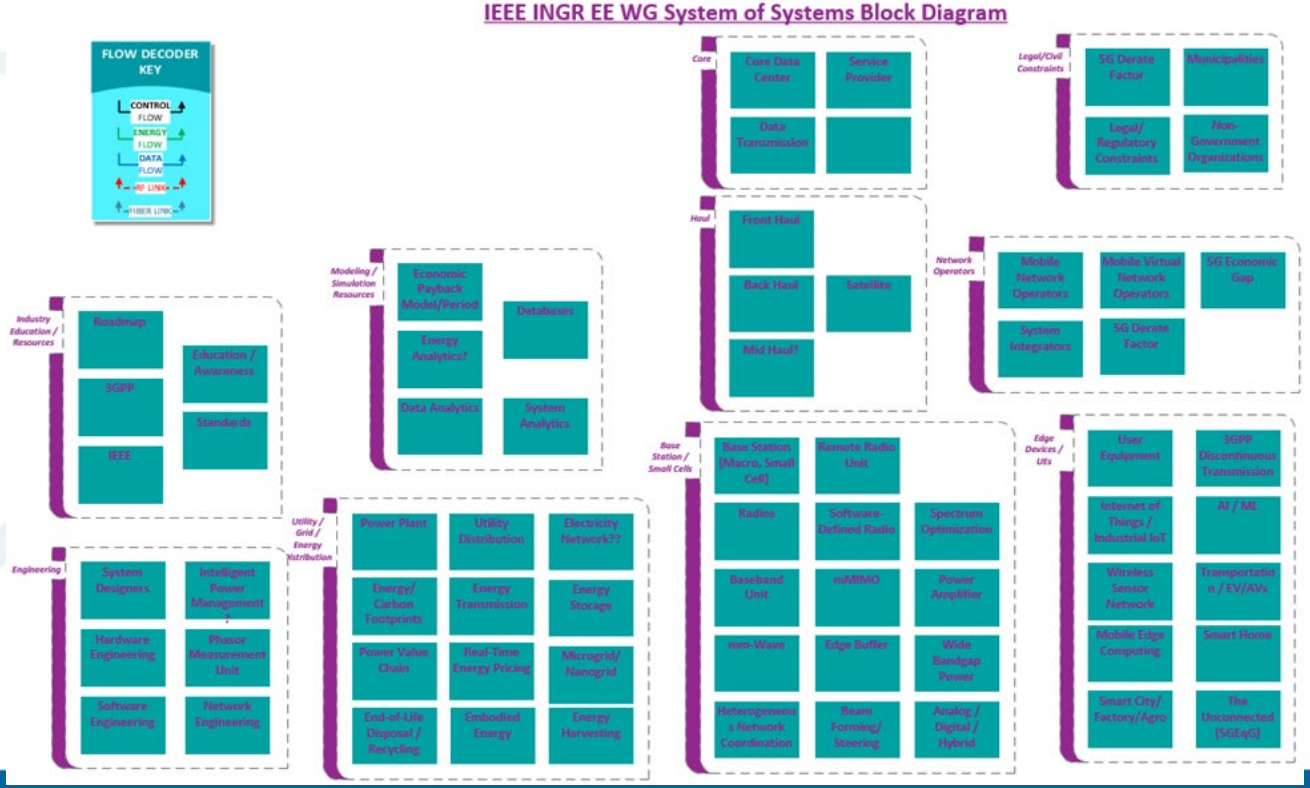
1. **Network Efficiency** (Edge Optimization, EE System Design Philosophies, Micro-to-Macro Assessment, 3GPP DTx, Data Centers)
2. **Small Cell Migration** (Macro-to-Micro Control Plane, Real-time Power Optimization, mmWave Impacts, Cell-free Architectures)
3. **Base Station Power** (mMIMO Impacts, Multi-band Support, Telemetry/Analytic Needs, Energy-centric Feedback Loops)
4. **Economic Factors** (Technical/Economic Analysis Enablement, Industry Metrics, Socioeconomic Impact, Energy-centric Network Simulation Models)
5. **Grid/Utility** (Utility-level Impacts/Risks, Networking Electricity, Real-time Energy Market Impacts)

Need for coordination

- Comprehensive, multi-level analysis and coordination is required to achieve the needed efficiency targets.
- Ripple effects across the ecosystem…
- Metrics/Models to harmonize technical & economic analyses across stakeholders with "universal currency" of energy.

	INGR Working Group Name	ACCESS				NETWORKS			SYS. & STANDARDS			ENABLERS & USERS				
		1. Massive MIMO	2. mmWave & Signal Processing	3. Hardware	4. Energy Efficiency	5. Edge Automation Platform	6. Satellite	7. Optics	8. Standardization Building Blocks	9. Testbed	10. System Optimization	11. Deployment	12. Applications & Services	13. Security	14. Connecting the Unconnected	15. Artificial Intelligence/ Machine Learning
	ACCESS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Massive MIMO		X	X					X	X						
2	mmWave and Signal Processing	X					X		X	X			X			
3	Hardware	X	X		X	X	X		X	X			X	X		
4	Energy Efficiency	X	X	X		X			X		X	X	X		X	X
	NETWORKS															
5	Edge Automation Platform	X								X			X	X	X	
6	Satellite	X	X	X	X	X		X	X				X	X		X
7	Optics*															
	SYSTEM AND STANDARDS															
8	Standardization Building Blocks	X	X	X	X	X	X	X		X	X	X	X	X	X	X
9	Testbed	X	X	X		X	X		X				X	X		
10	System Optimization*															
	ENABLERS AND USERS															
11	Deployment	X	X							X			X	X		
12	Applications and Services	X	X	X	X	X	X	X	X	X	X	X		X	X	X
13	Security	X	X			X			X	X	X		X		X	X
14	Connecting the Unconnected				X	X	X		X	X	X	?	X	X		
15	Artificial Intelligence/Machine Learning*															

An Ecosystem Made of Many, Partially Siloed Stakeholders



How can they “talk” to each other?

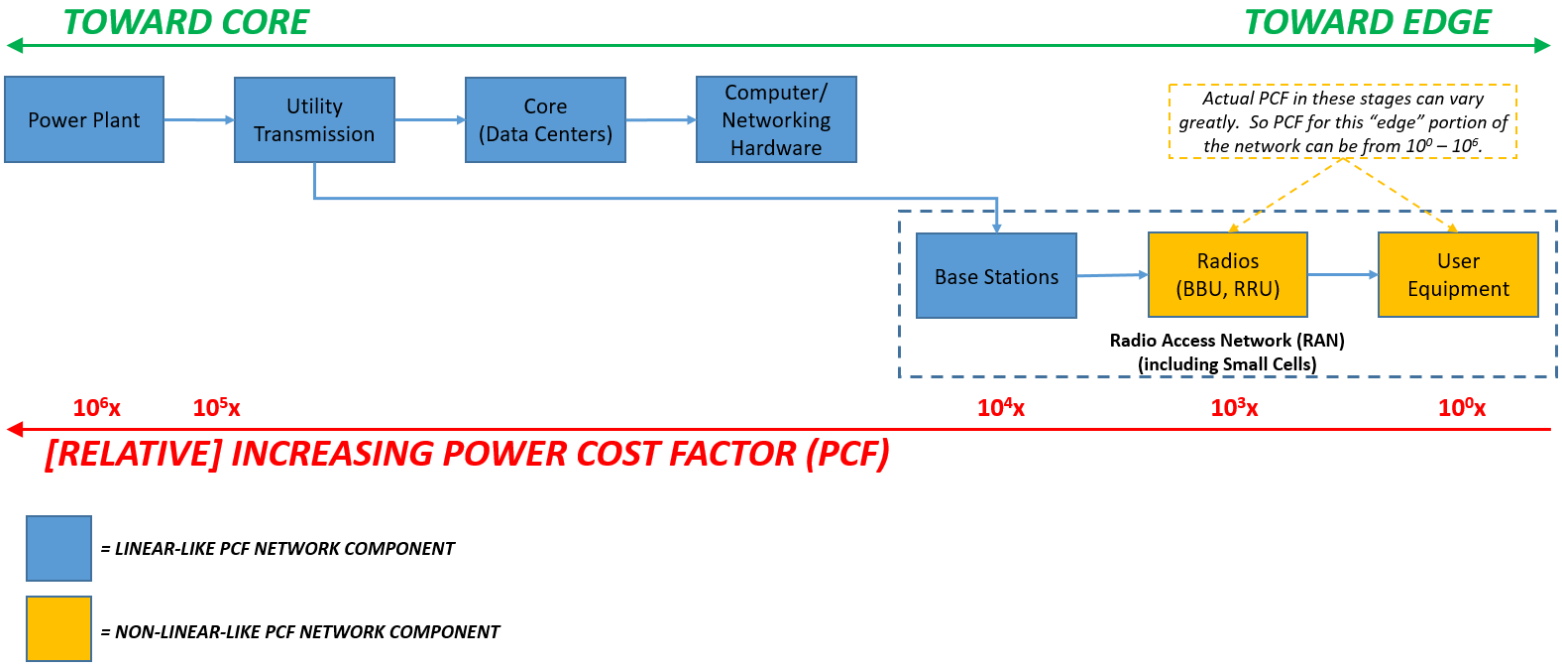
- Select a common “language:” the global “currency” of energy.
- Enable interconnection of subsystems with the use of a standardized “black box” definition.
- Define input variables that are “block-specific.”
- Define standardized output variables that enable (i) connecting the sub-systems, (ii) assessing bottlenecks and (iii) optimizing system efficiency (delivered performance/cost).

We Needed a New Lexicon and Metrics

- A way to relate blocks in terms of the flow of energy from generation to consumption: the ***Power Value Chain (PVC)***
- A way to assess blocks in terms of global energy impact: the ***Power Cost Factor (PCF)***
- A way to describe the impact of bottlenecks, which cause a reduction of overall system performance from the designed objectives: the ***5G Derate Factor (5GDF)***

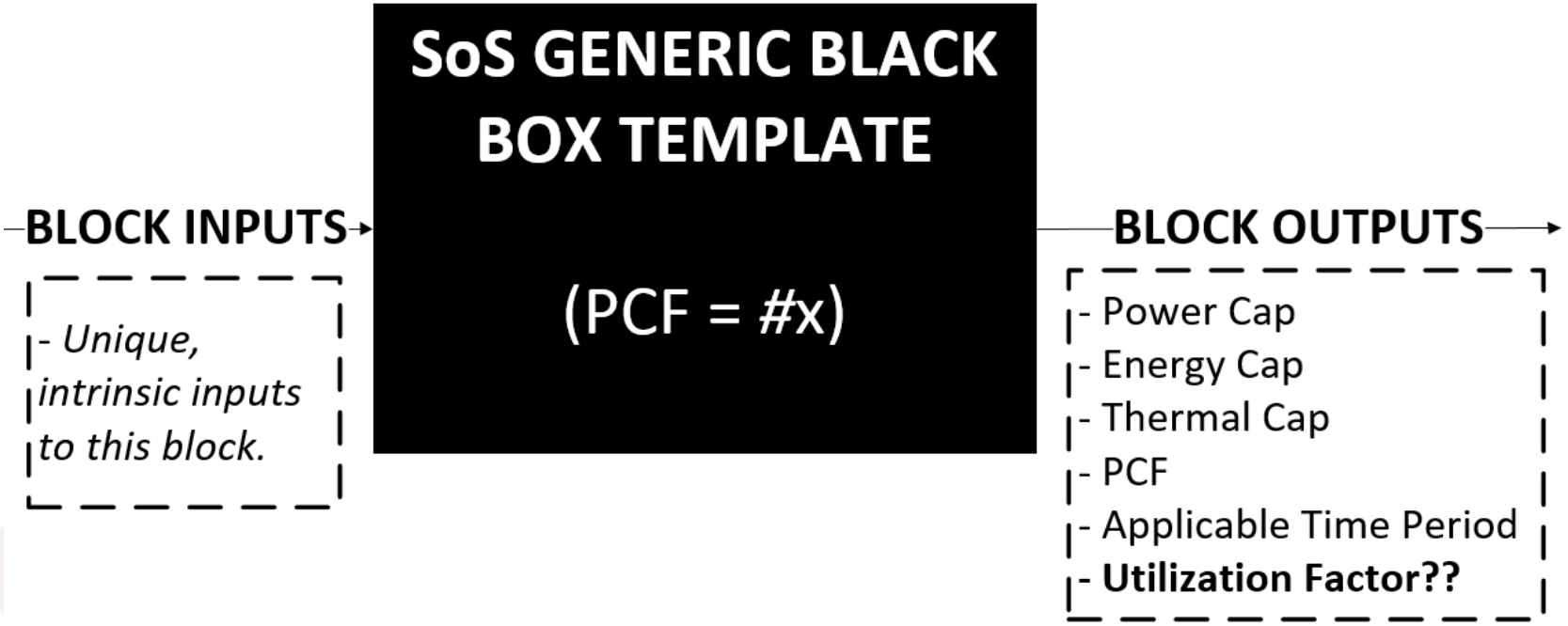
Linking the Heterogeneous Subsystems

The 5G Power Value Chain



Defining the “Black Box”

BLACK BOX TEMPLATE:



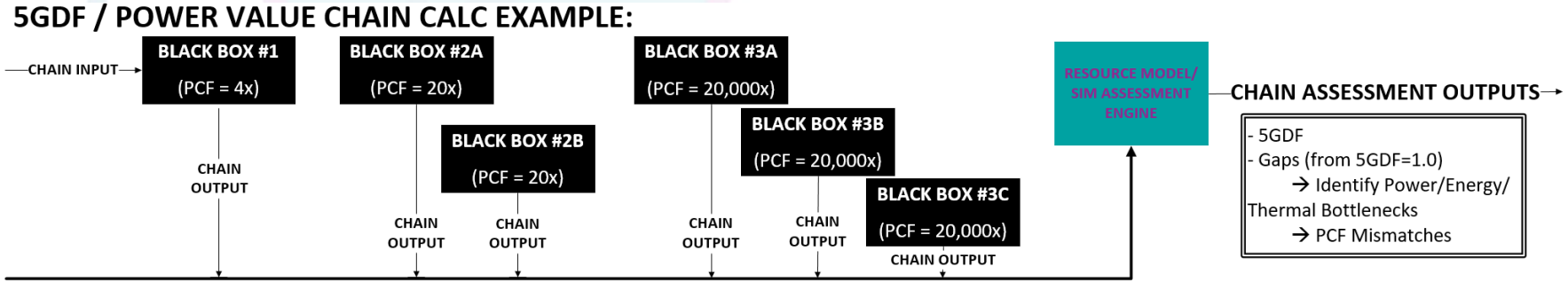
Defining the “Black Box”

- **Inputs**: “performance demand” placed on that block. A static or dynamic set of values, depending on the analysis we want to conduct.
- **Outputs**: the most important factors that impact the box’s energy footprint and utilization factor.
- **Input to Output relationships**: a set of functions that can be easily defined by the “experts” for the block, and can be updated for “what if” analyses and assessment of future performance expectations.

THE PVC CHAIN ANALYSIS

1: Static Assessments

- Energy Footprint Based on Designed Performance
- System Bottlenecks Due to Energy Caps

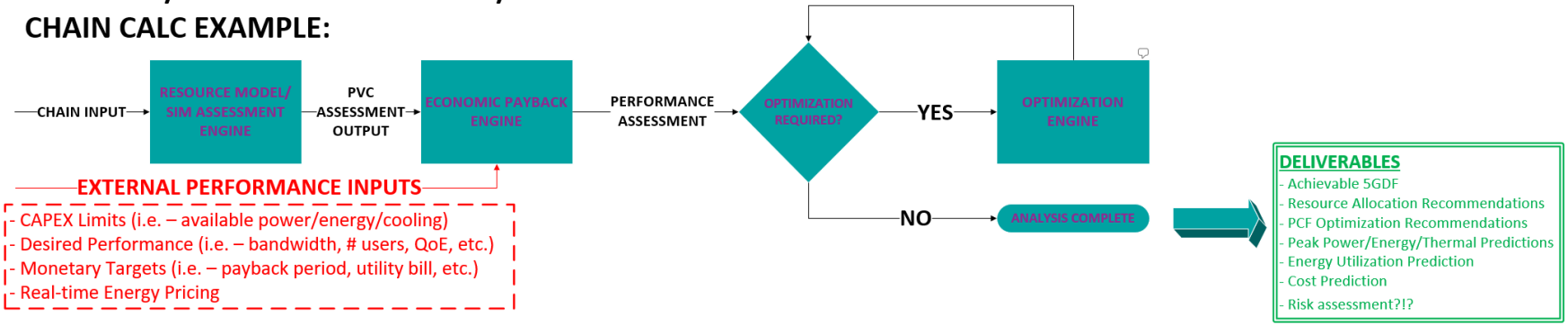


THE PVC CHAIN ANALYSIS

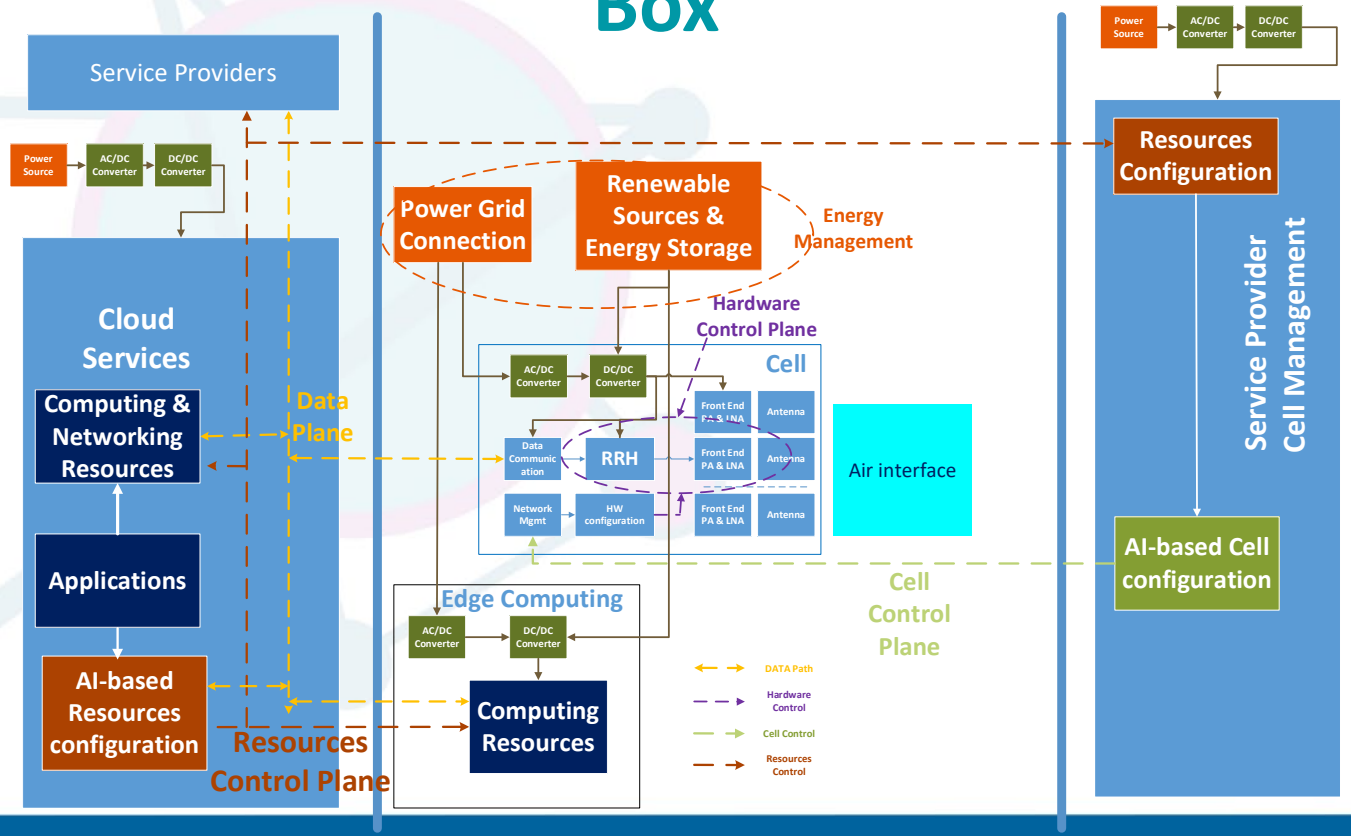
2: Dynamic Assessments

- System Optimization
- Financial Analysis

NETWORK/SYSTEM OPTIMIZATION/UTILIZATION CHAIN CALC EXAMPLE:



Each Sub-block Can Be Represented by a “Black Box”



Implementing the System of Systems (example)

SUB-BLOCK EXAMPLE *(arbitrary)*:

BLOCK INPUTS

- Available Bandwidth
- Traffic Serviced
- QoS/QoE
- Spectral Efficiency
- Applicable Time Period
- Environmental Factors

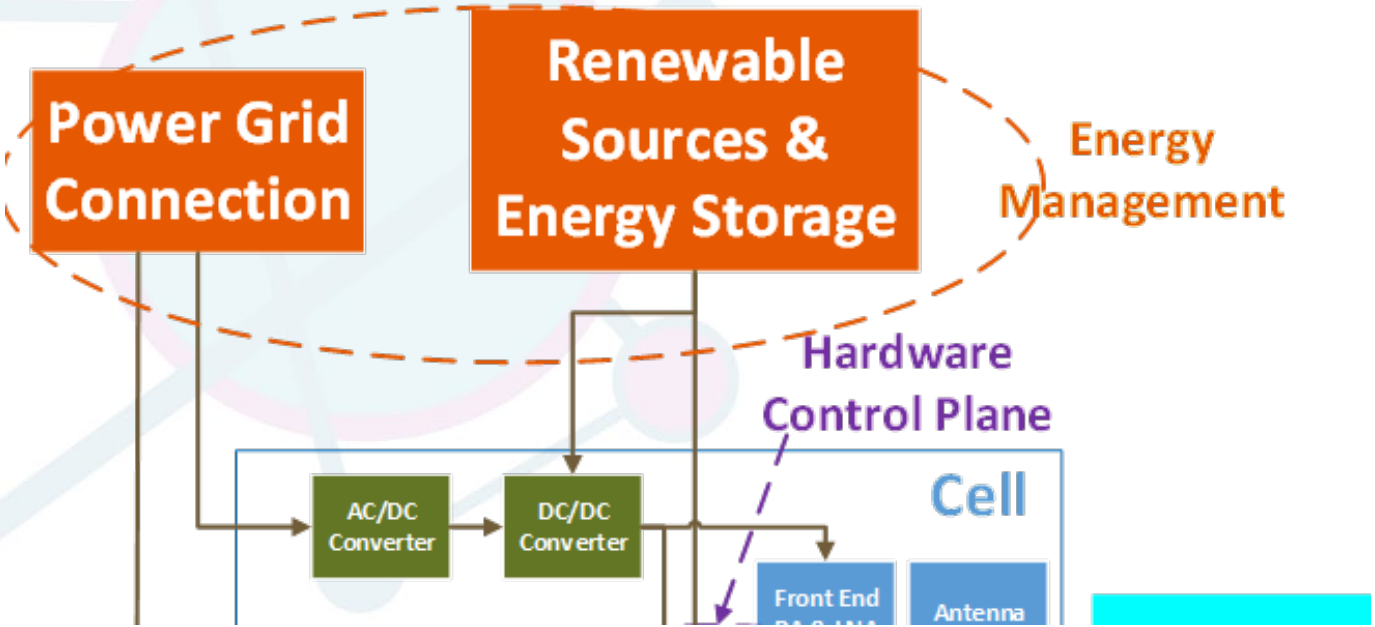
SMALL CELL BASE STATION

(PCF = 20x)

BLOCK OUTPUTS

- Power Cap
- Energy Cap
- Thermal Cap
- PCF
- Applicable Time Period
- **Utilization Factor??**

Energy Sources Optimization (Static or Dynamic)



The Steps in the Process: Divide and Conquer

- Determine which black box(es) from the SoS are to be assessed.
- Determine the appropriate stakeholders and subject matter experts to apply to the template assessment.
- Determine the appropriate block inputs (e.g. – key characteristics unique to the block in question).
- Determine the relation of the block inputs to the block outputs and translate into a sub-block diagram.
- Translate the sub-block model into proposals for functions that relate block inputs to the universal block outputs.
- Provide the information to the EE WG for integration into the full SoS.

Stakeholders

ALL OF THEM!!! (EE TOUCHES ALL)

- No Stakeholder Without Direct Impact/Consequence Related to Energy Efficiency
- No Real Value In Listing Out Even Major/Marketing Groups (i.e. – HW, SW, Economic, Business Development, Municipalities, NGOs, etc.)

Contributing Working Group Members

- **Brian Zahnstecher, PowerRox**
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- Laurence McGarry, pSemi/Murata
- Lin Nease, HPE
- Bruce Nordman, Lawrence Berkeley National Laboratory
- Magnus Olsson, Huawei
- Bill Vassilakis, NewEdge
- *Earl McCune, Eridan Communications* ***(IN MEMORIAM, RIP)***

Get involved!

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Read our Whitepaper at
https://futurenetworks.ieee.org/images/files/images/roadmap/INGR_EnergyEfficiency_WP.pdf

QUESTIONS?