
Scenario Development for DARPA Spectrum Collaboration Challenge (SC2)

Binoy Kurien

MIT Lincoln Laboratory

November 15th, 2017



This research was developed with funding from the Defense Advanced Research Projects Agency (DARPA).
The views, opinions and/or findings expressed are those of the author and should not be interpreted as
representing the official views or policies of the Department of Defense or the U.S. Government.



Where This Talk Fits in the Overall Workshop



Spectrum Collaboration Challenge – Challenges

Collaborate Without Co-Design



Create radio networks that work with others without knowing how they "think"

Engineer Emergent Effects



Discover and solve issues that only arise in large-scale realistic settings

Communicate Without Constraints

too specific

too general

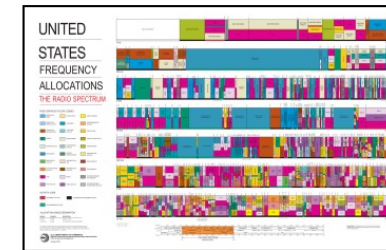


frame 15, slot 7



Create a protocol that supports evolving new forms of collaboration

Evolve The Ecosystem



Change radio design, applications, and spectrum management to enable and leverage collaboration.



Thumbs-up image source: <http://sr.photos3.fotosearch.com/bthumb/CSP/CSP880/k8803233.jpg>
Pencil image source: <http://www.pngall.com/wp-content/uploads/2016/03/Pencil-PNG.png>

DISTRIBUTION A. Approved for public release: distribution unlimited.



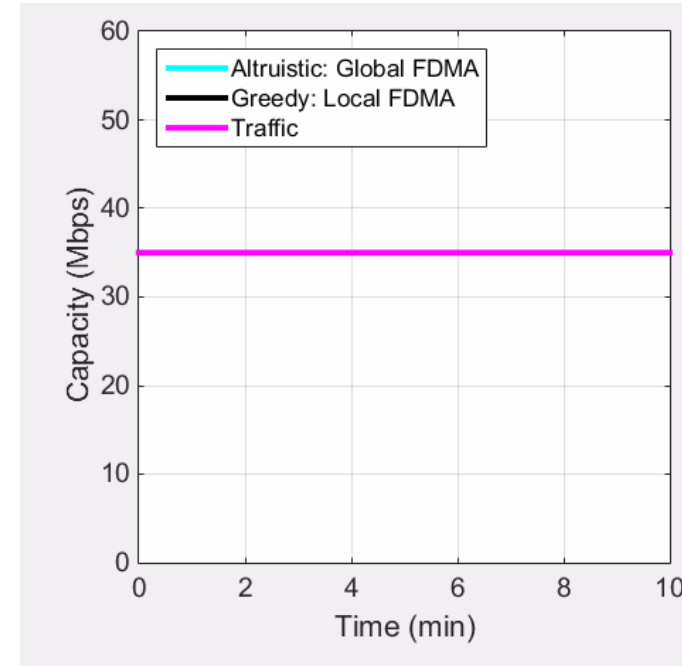
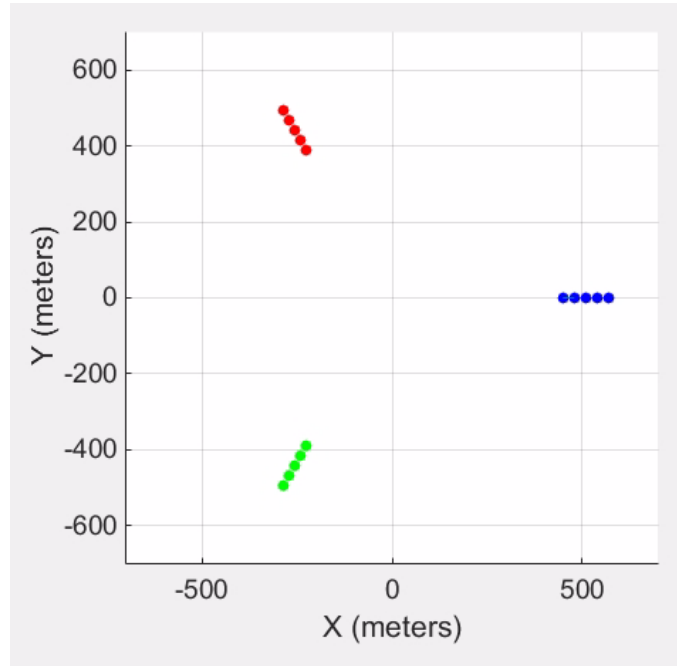
Outline

- **SC2 Scenario Motivations: *What questions are we asking in SC2 Scenarios?***
 - Role of collaboration among heterogeneous networks
- **Bringing Scenarios to reality: *How are we mapping concepts onto SC2 Colosseum?***
 - Fundamental challenge: emulation of wireless continuum with digital equipment
- **Getting down to brass tacks: *What constitutes an SC2 Scenario?***



Example Q1: Can CIRNs determine when they need to coordinate spectrum access?

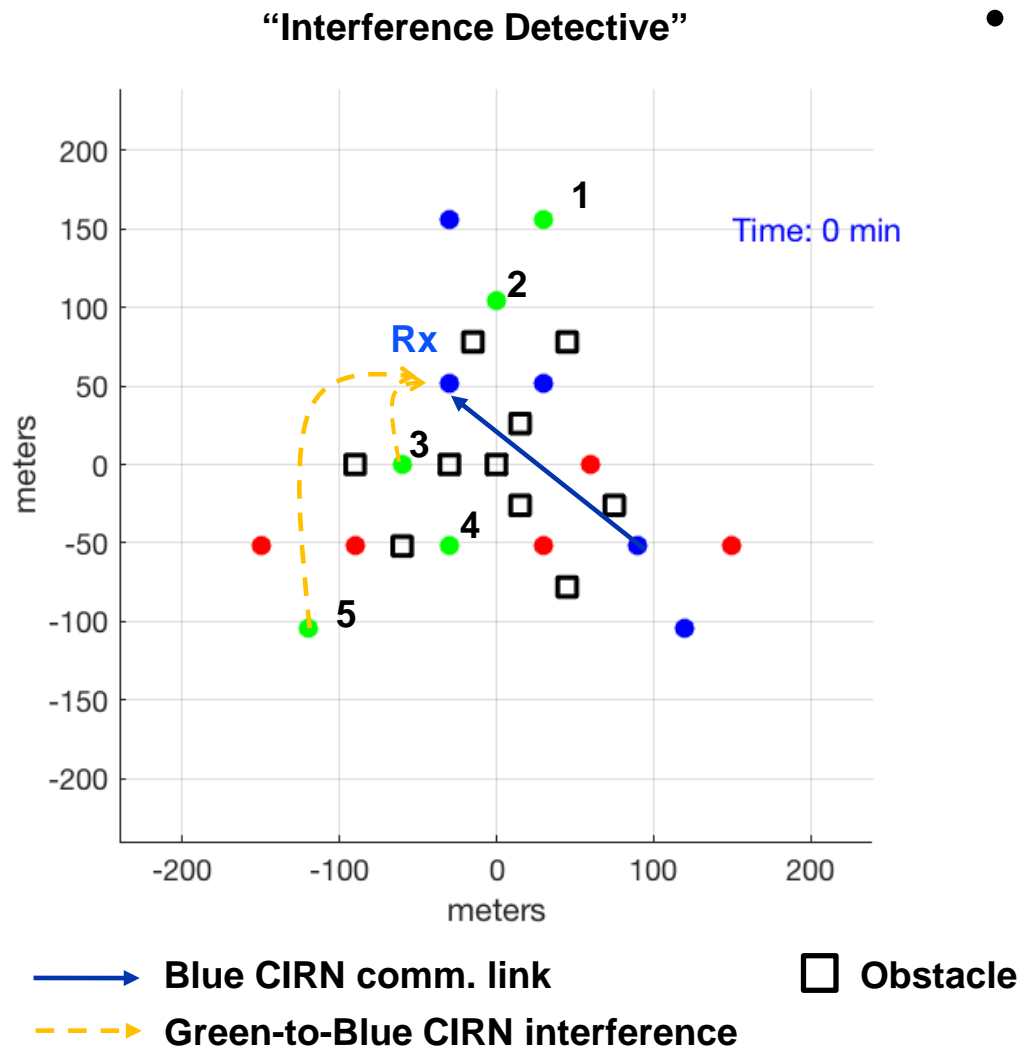
“N-Corners”



- **Regime 1: When their interference environments are isolated, CIRNs benefit from greedy spectral usage**
- **Regime 2: Congestion necessitates coordination (e.g. “global” FDMA)**
- **Several SC2 scenarios test the ability to detect and adapt to such regime changes**



Example Q2: Can CIRNs collaboratively adapt to complex interference environments?

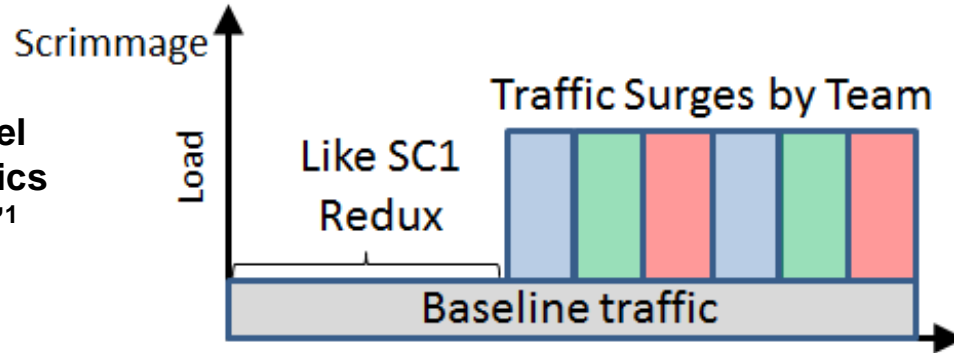


- **Motivation: real-world interference environments can be highly *asymmetric***
 - Suppose CIRNs collide in time-frequency space
 - Impact severity may differ greatly among colliding parties
 - simple reactive schemes can be highly sub-optimal
 - in contrast, collaboration is a key mechanism for solving inter-CIRN *hidden node* problems
 - **Example (left):**
 - Co-channel interference from Green Node 3 severely impacts Blue receiver node (Rx)
 - Green CIRN relies on feedback from Blue CIRN that its Gateway node is vulnerable to interference
 - By collaboratively mapping interference, Green CIRN learns Nodes 3 and 5 should de-conflict spectrum access with Node Rx, whereas its other nodes can be greedy

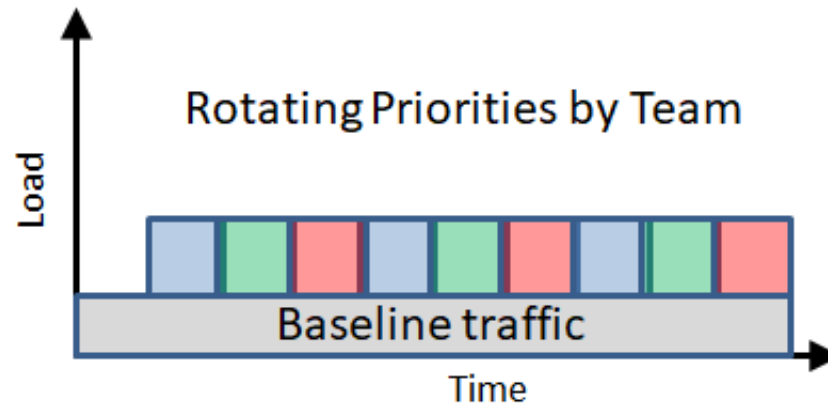


Example Q3: Can CIRNs collaboratively adapt to complex traffic profiles?

Network-Level
Traffic Dynamics
“Hot Potato”¹



Network-Level
Priority
“WhosTheBoss”¹



- Real-world traffic profiles are complex:
 - Periodic surges in demand
 - Multiple levels of priority: some flows critical, others “best-effort”
- CIRNs should be able to respect relative traffic priorities and demand among:
 - Different CIRNs collectively
 - Individual links with the CIRNs
 - Multiple simultaneous flows

1. Scenario Developer: Jody Neel, Federated Wireless
2. Scenario Developer: Ranga Reddy, Echo Ridge



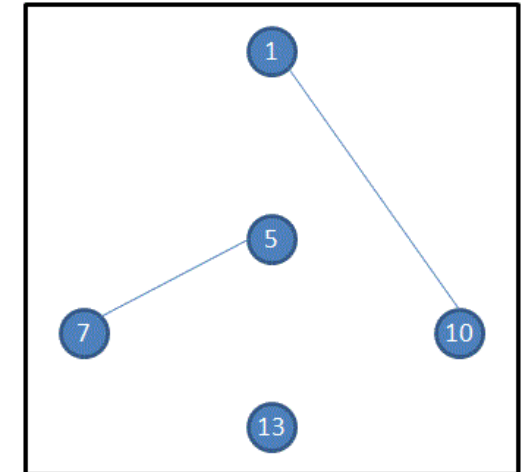
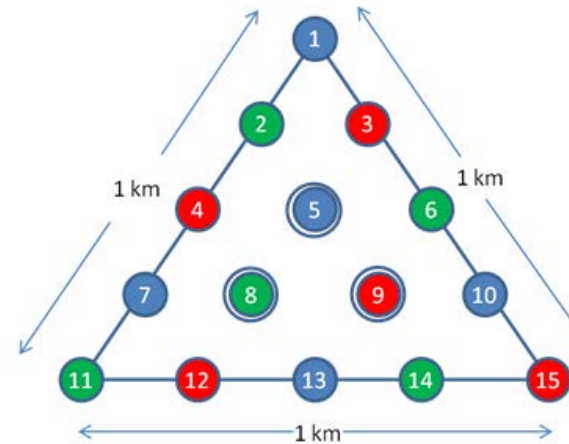
Example Q3: Can CIRNs collaboratively adapt to complex traffic profiles?

Realistically-Diverse Traffic Portfolios “San Diego Wildfire”¹



IP Traffic Flows	Flow Rate (kbps)	Transport	Priority Level
Ctrl Traffic	10	TCP	Highest
VOIP	32	UDP	High
Imagery	204.8	TCP	Medium
Video	750	UDP	Medium
Position-Location Information (PLI)	0.40	UDP	Low

Dynamic Links “Cut-Throat”²



- Dynamic links in a tightly-packed environment gauge the reflexes of:
 - Intra-CIRN MAC schemes
 - Inter-CIRN collaborative spectrum sharing schemes

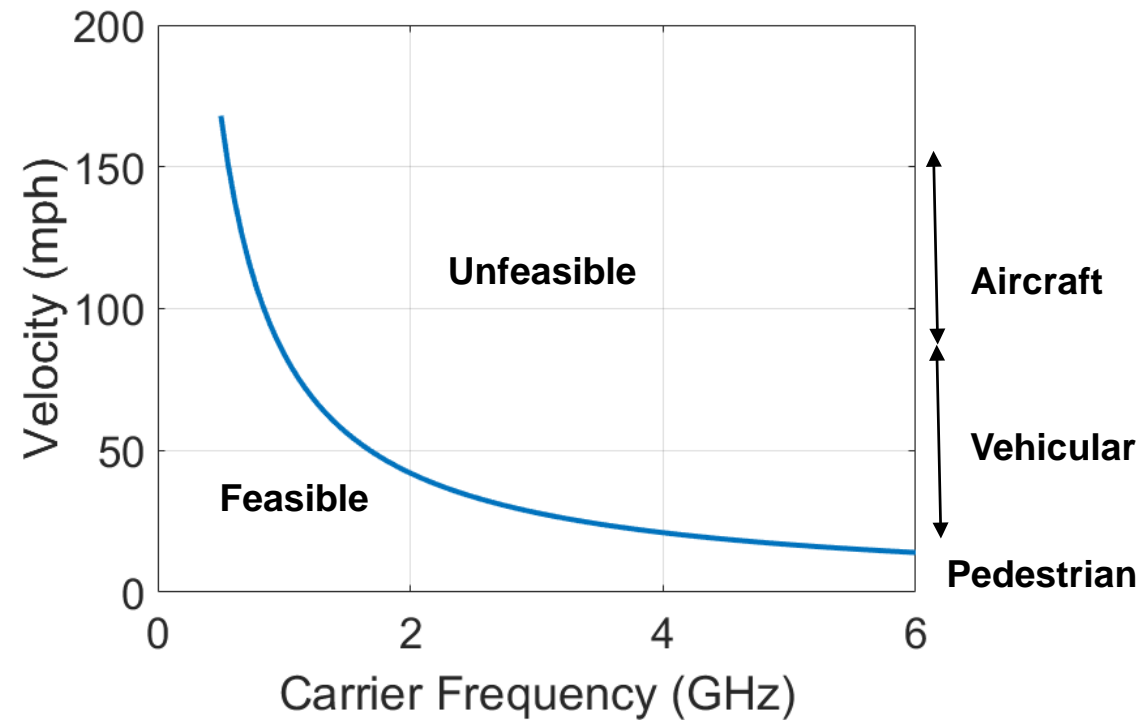
1. Scenario Developer: Ranga Reddy, Echo Ridge
2. Scenario Developer: Jody Neel, Federated Wireless



Mapping Concepts to Reality

Constraint 1: Coherence Time

- **Colosseum has finite 1-msec channel tap update rate**
 - **We can only accurately model channels with coherence times greater than 1-msec**
 - **Constraint maps to a region of feasible (velocity, frequency) pairs**

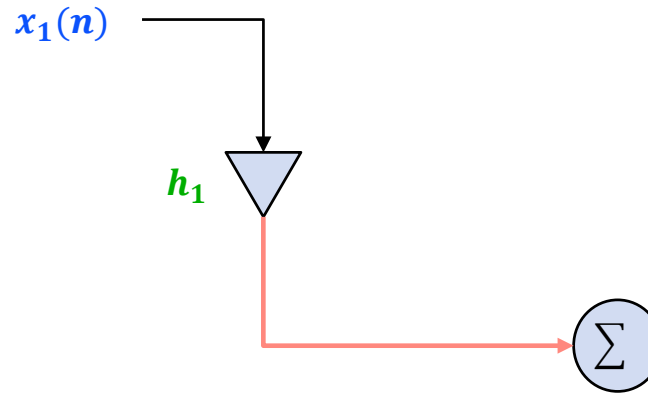
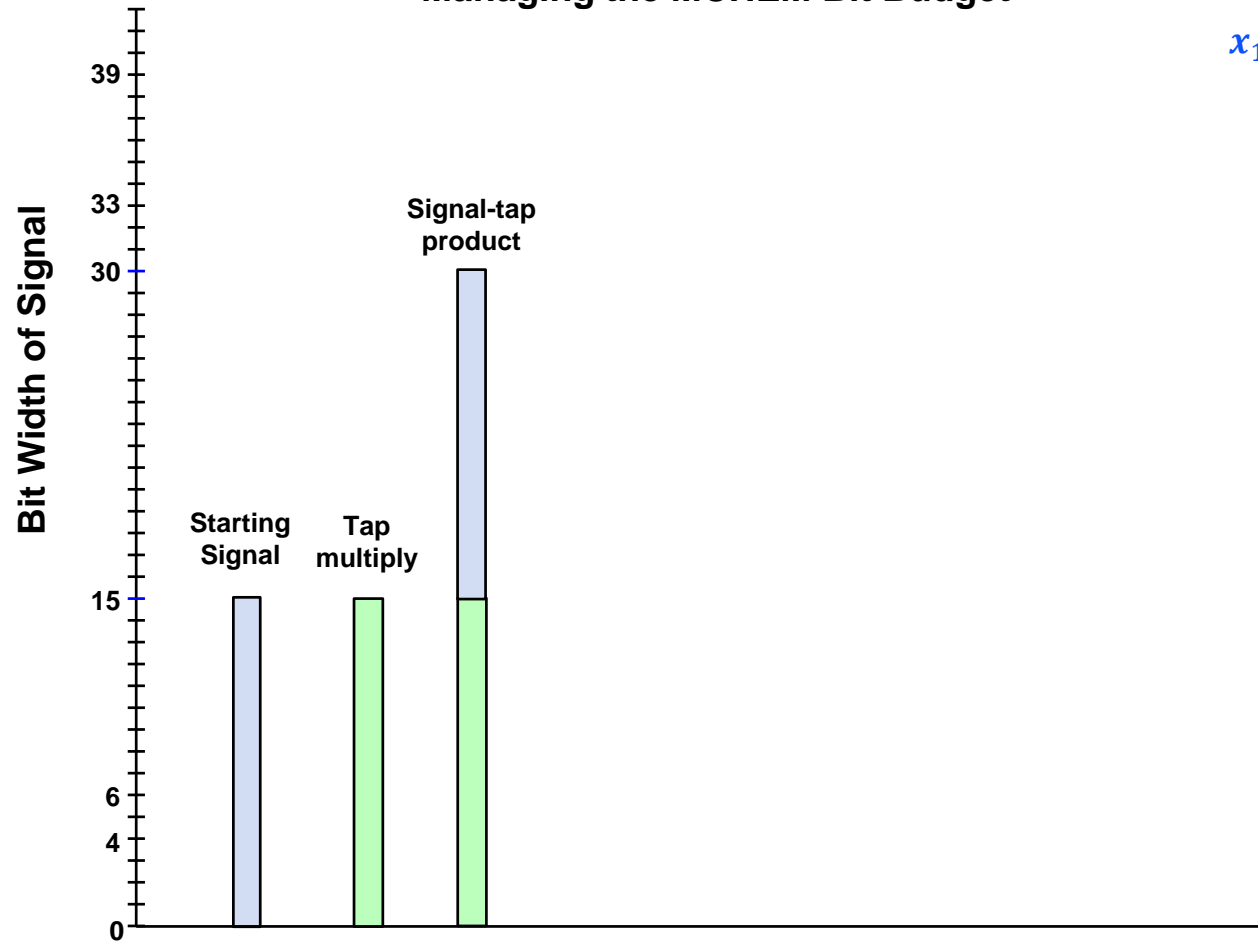




Mapping Concepts to Reality

Constraint 2: Dynamic Range

Managing the MCHEM Bit Budget

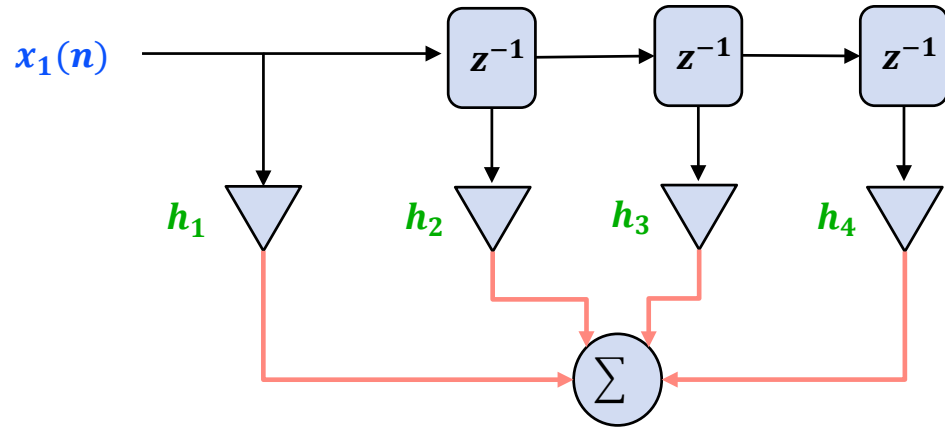
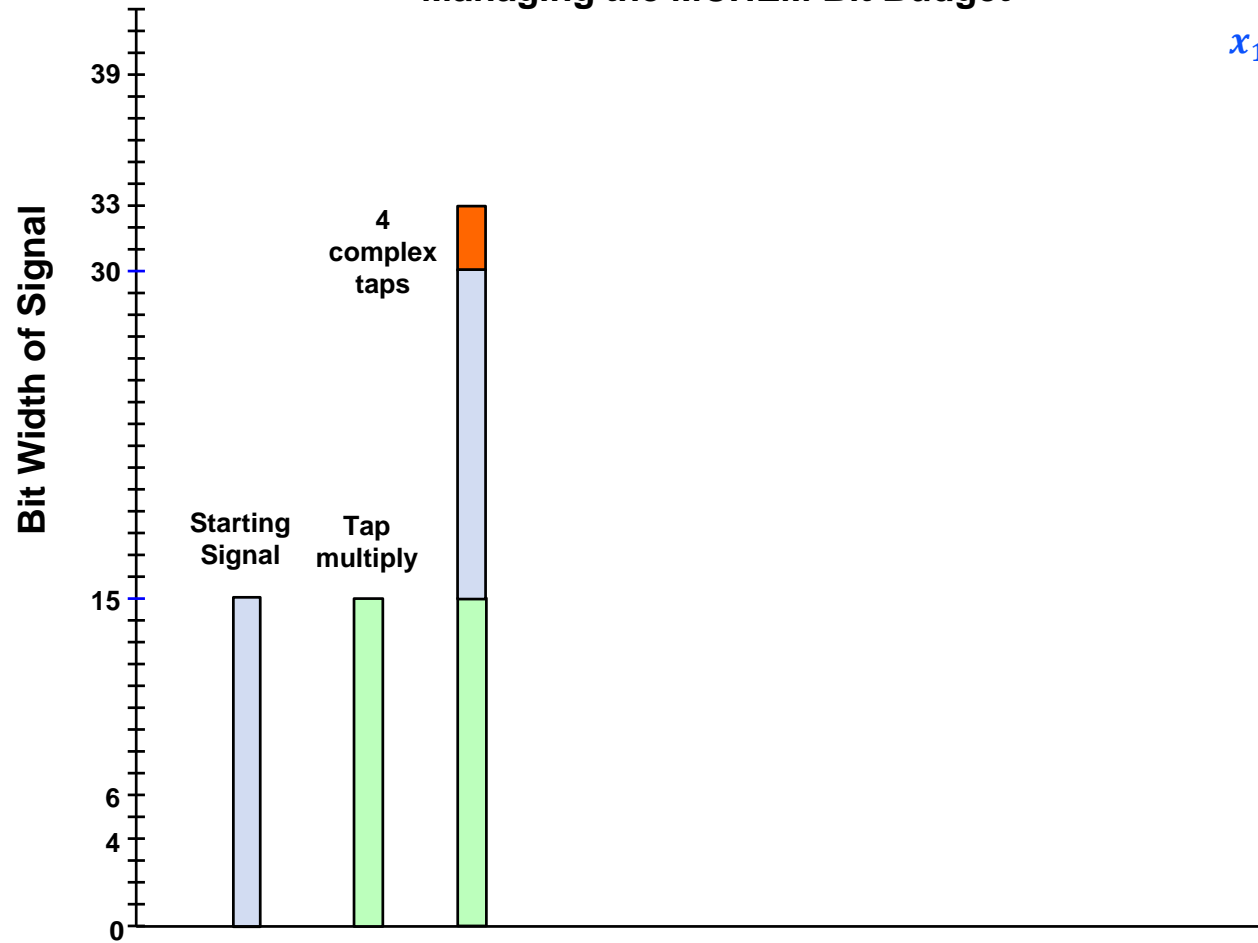




Mapping Concepts to Reality

Constraint 2: Dynamic Range

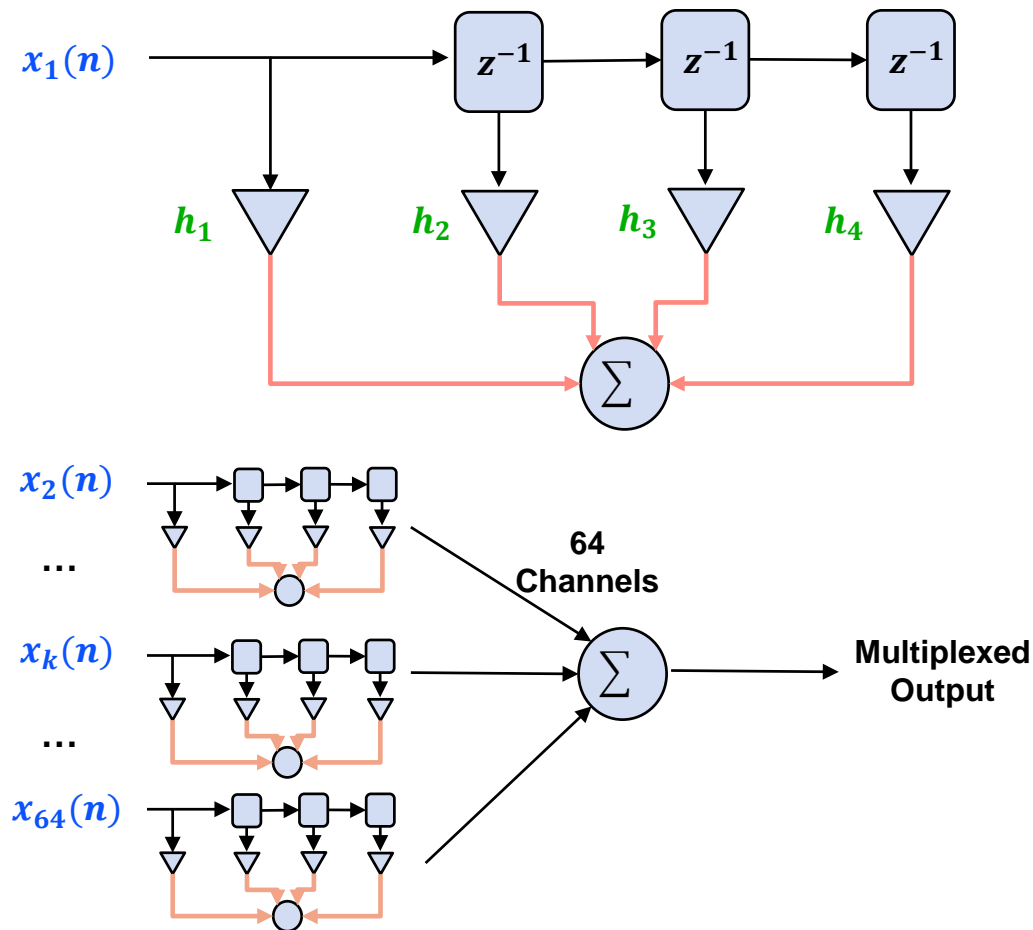
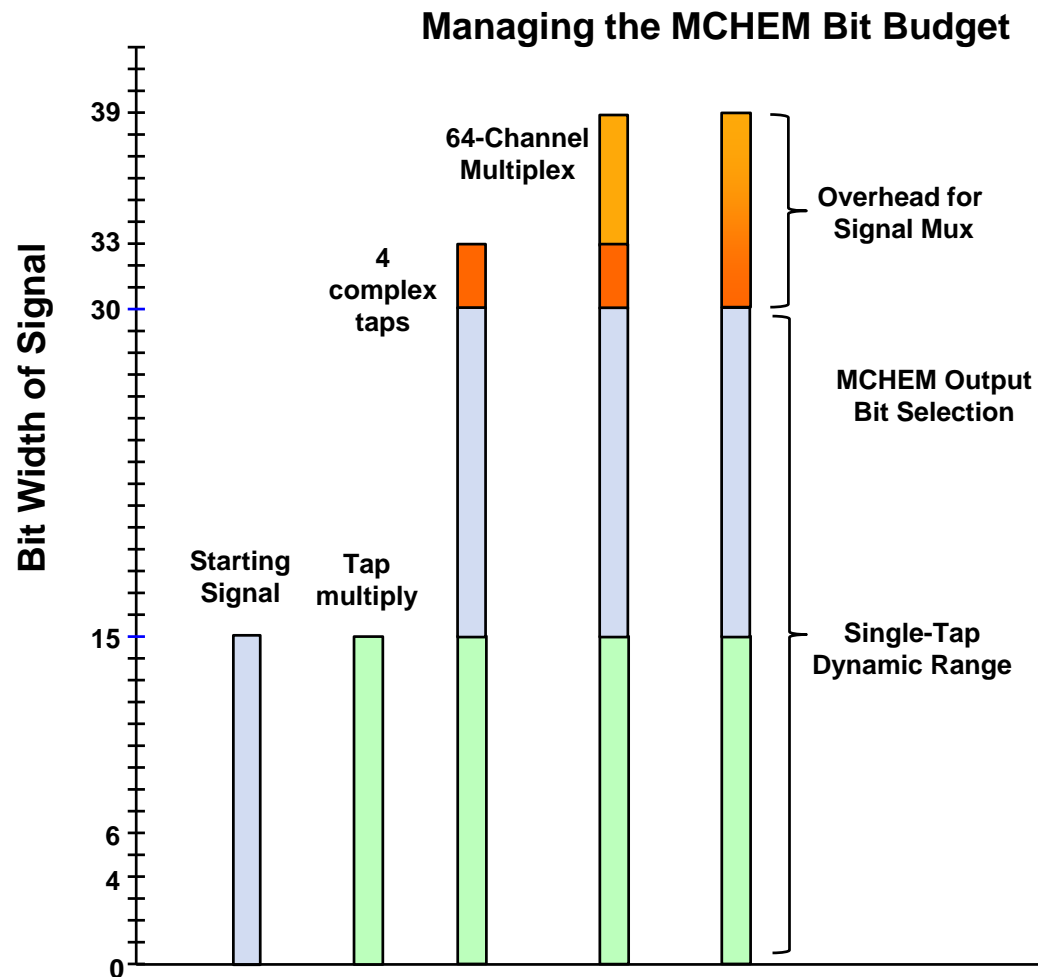
Managing the MCHEM Bit Budget





Mapping Concepts to Reality

Constraint 2: Dynamic Range

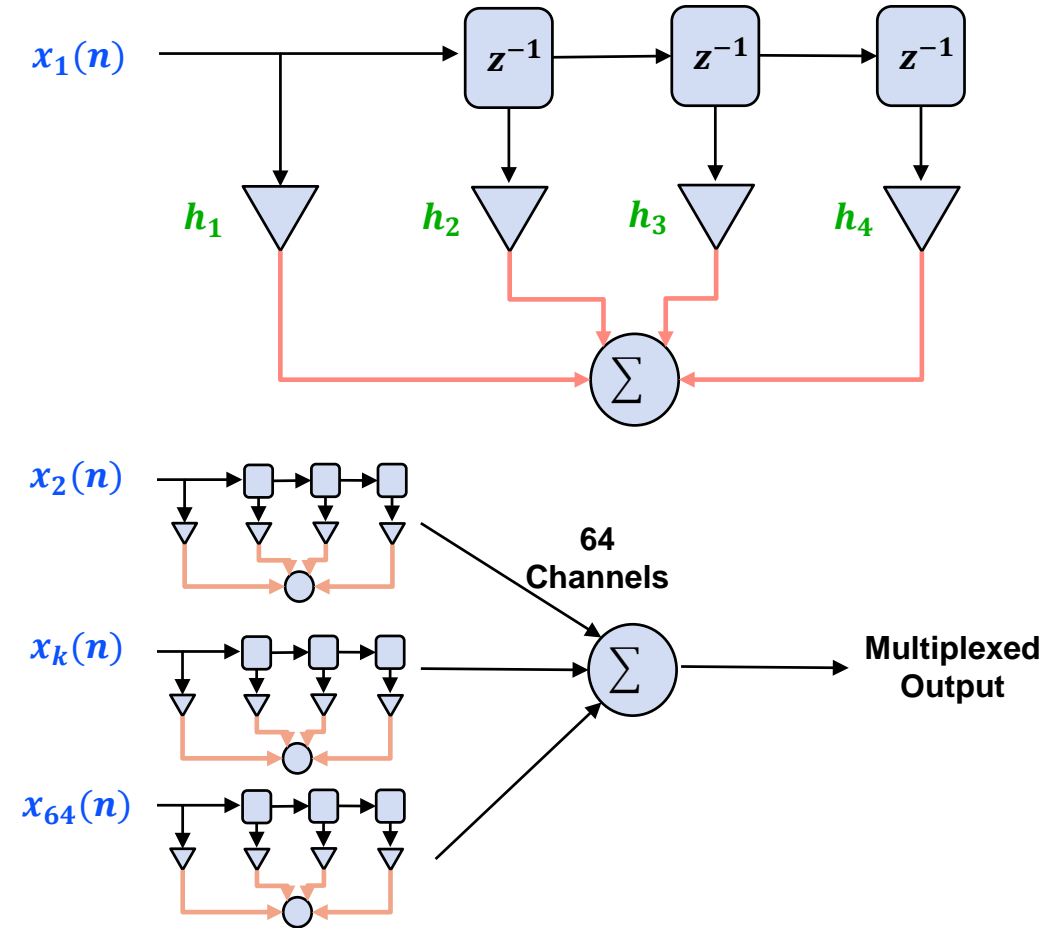
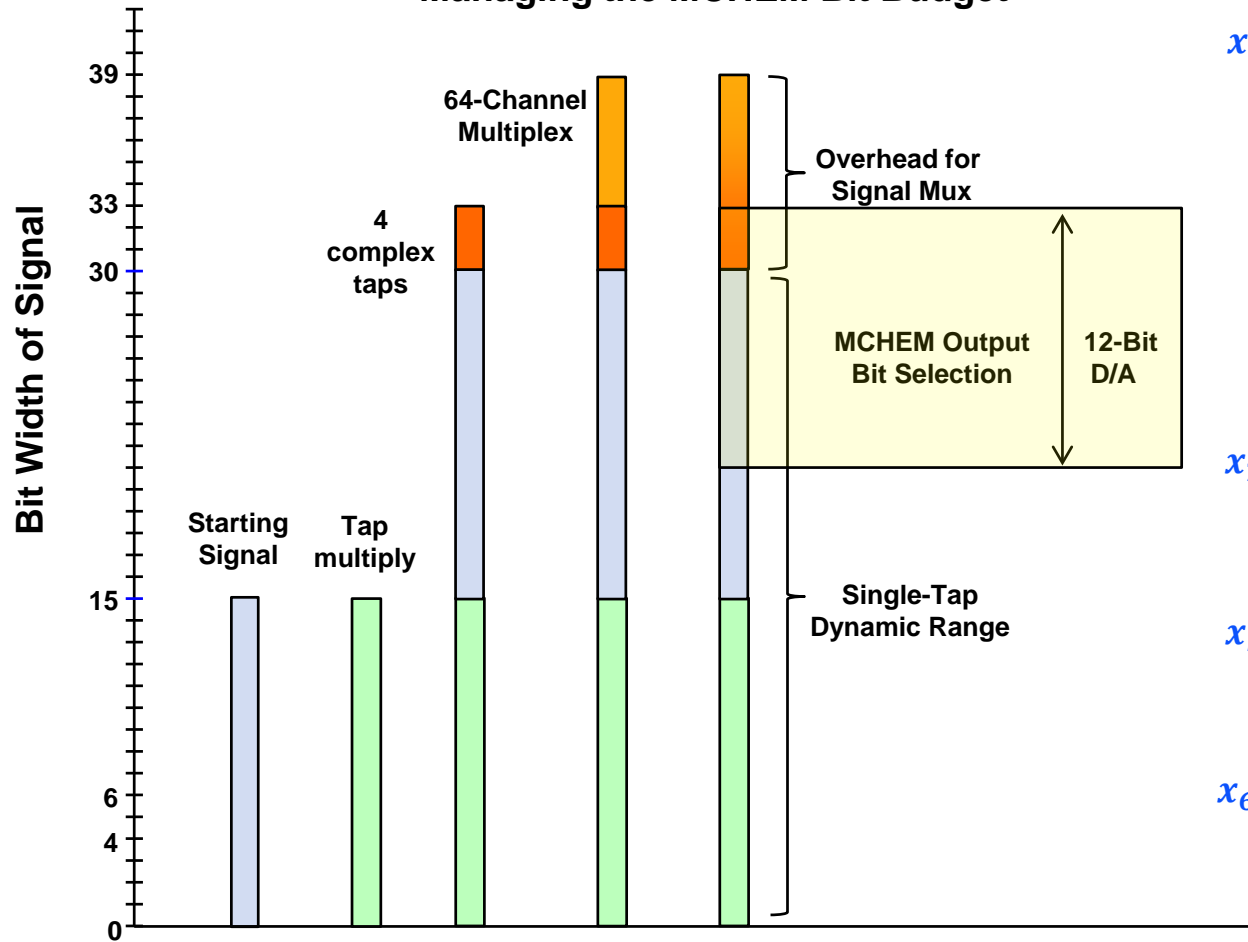




Mapping Concepts to Reality

Constraint 2: Dynamic Range

Managing the MCHEM Bit Budget

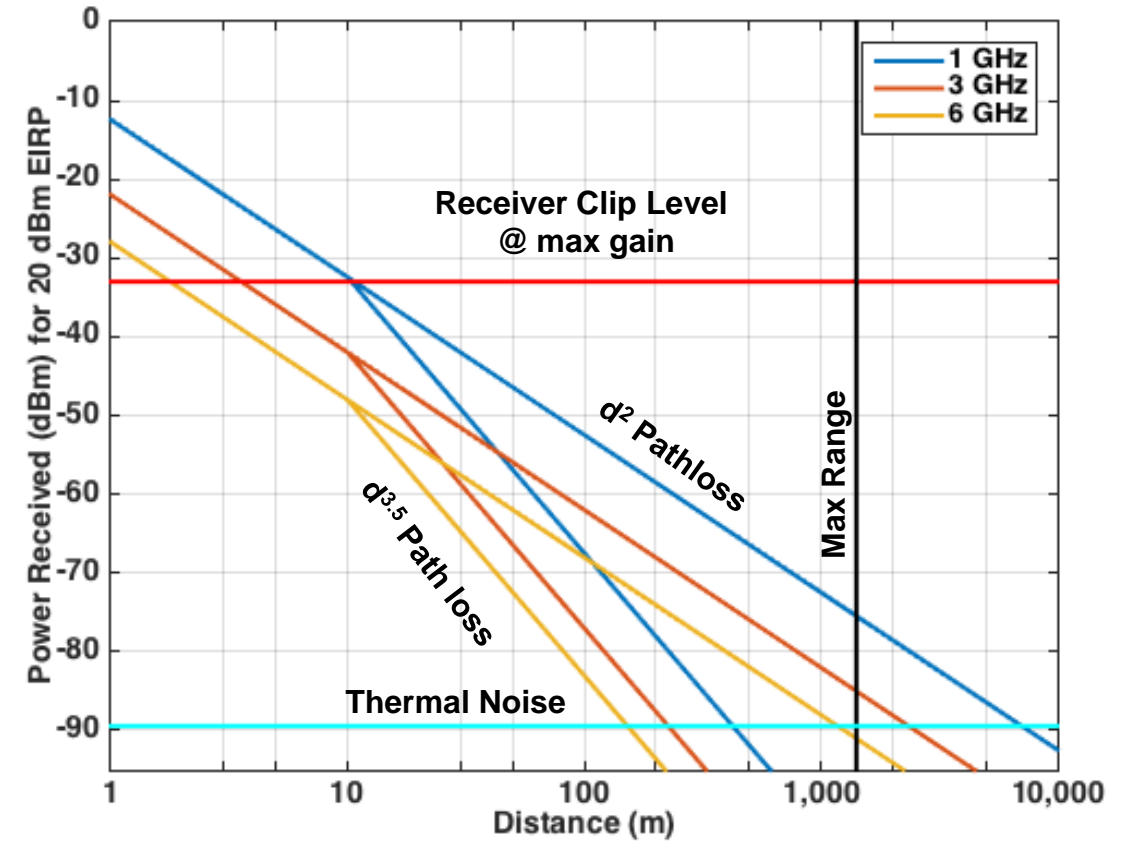
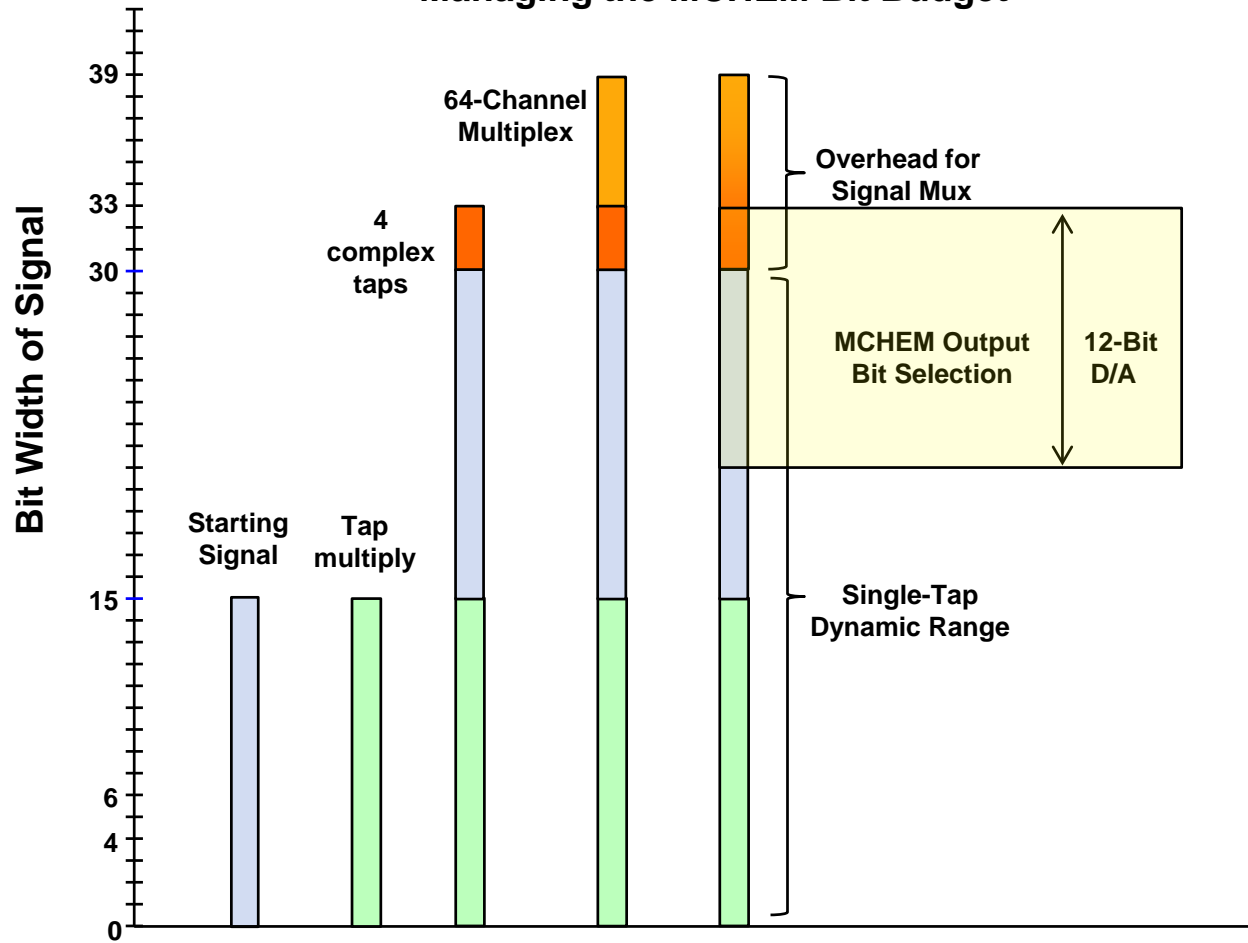




Mapping Concepts to Reality

Constraint 2: Dynamic Range

Managing the MCHEM Bit Budget

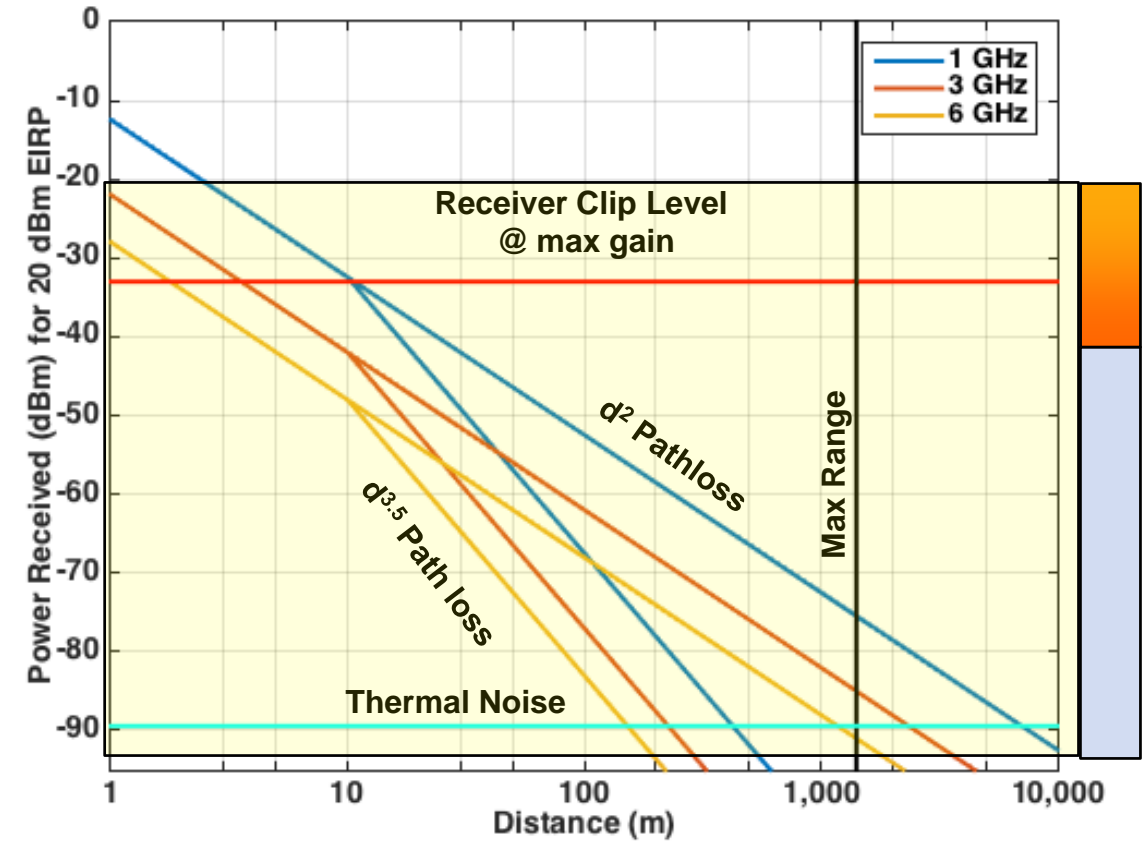
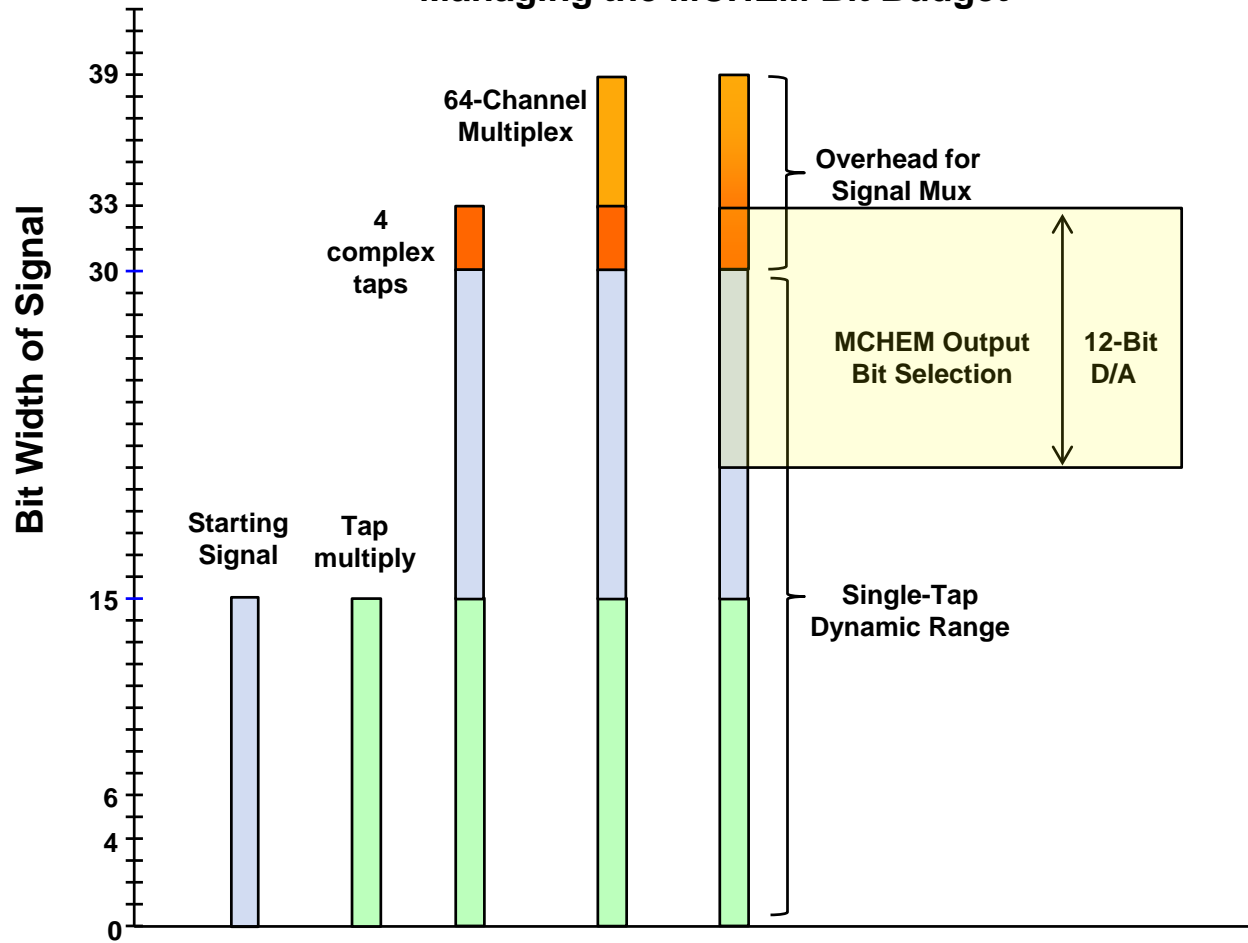




Mapping Concepts to Reality

Constraint 2: Dynamic Range

Managing the MCHEM Bit Budget

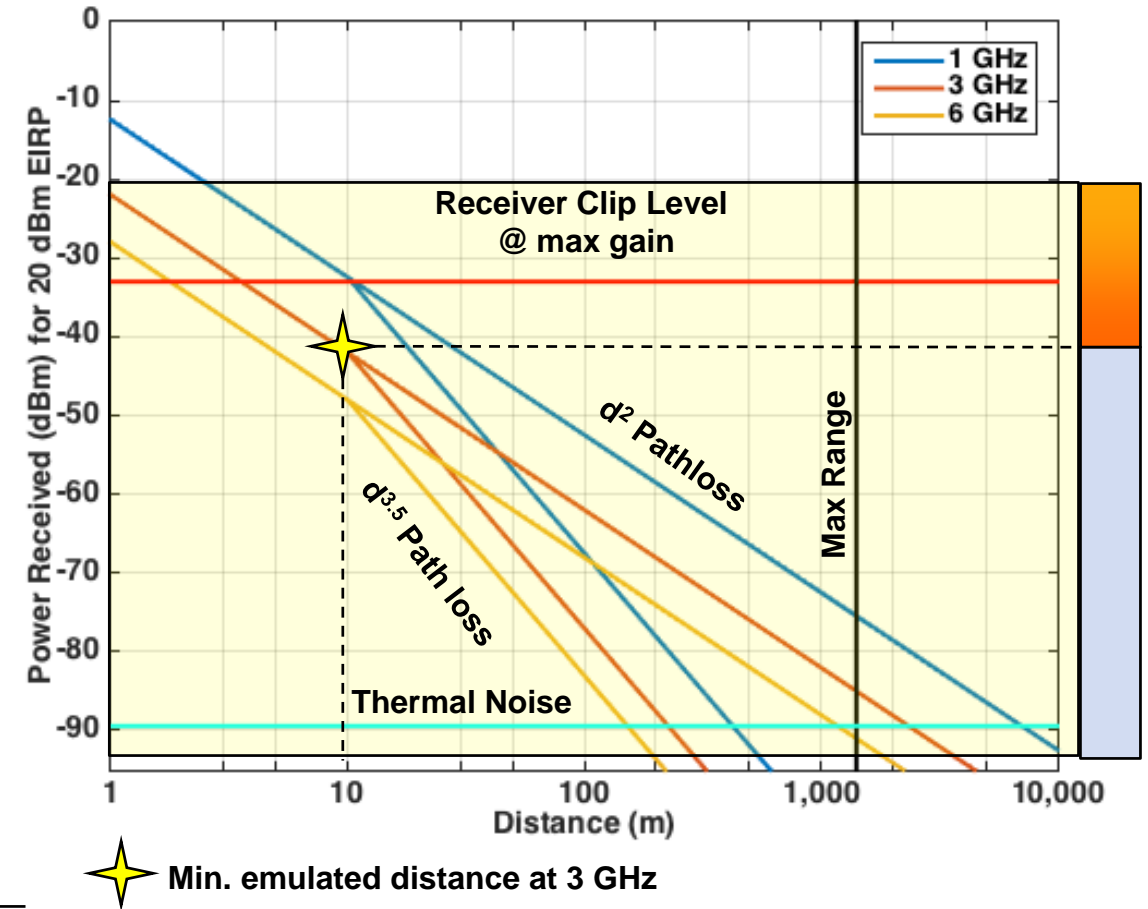
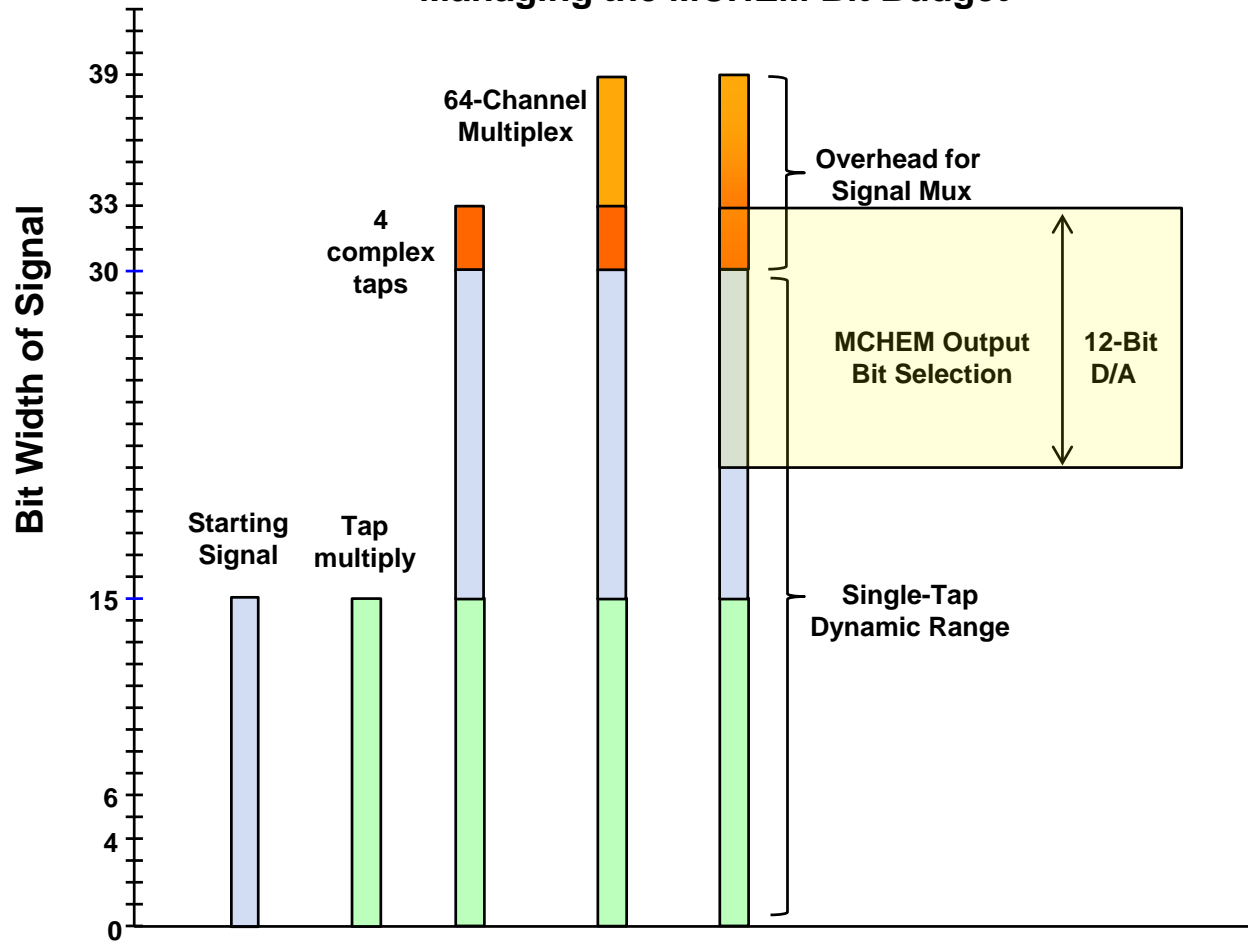




Mapping Concepts to Reality

Constraint 2: Dynamic Range

Managing the MCHEM Bit Budget

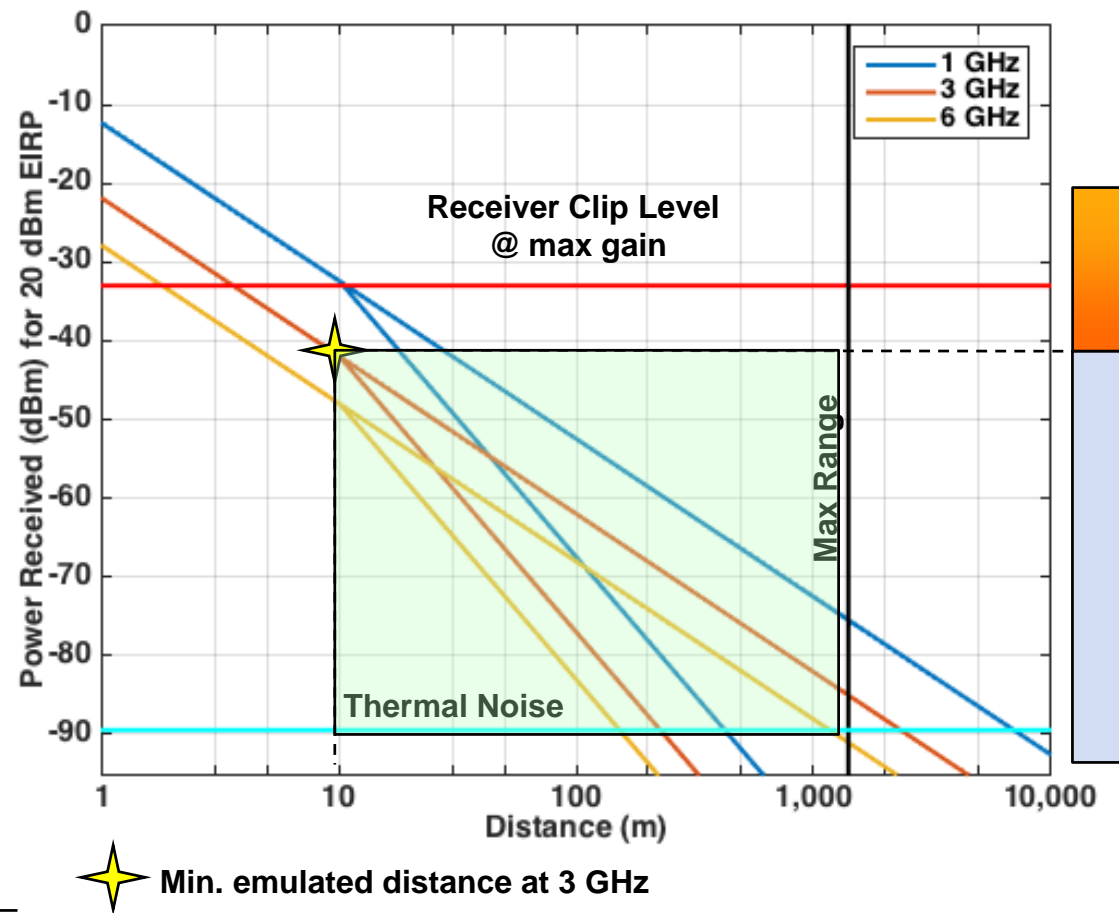
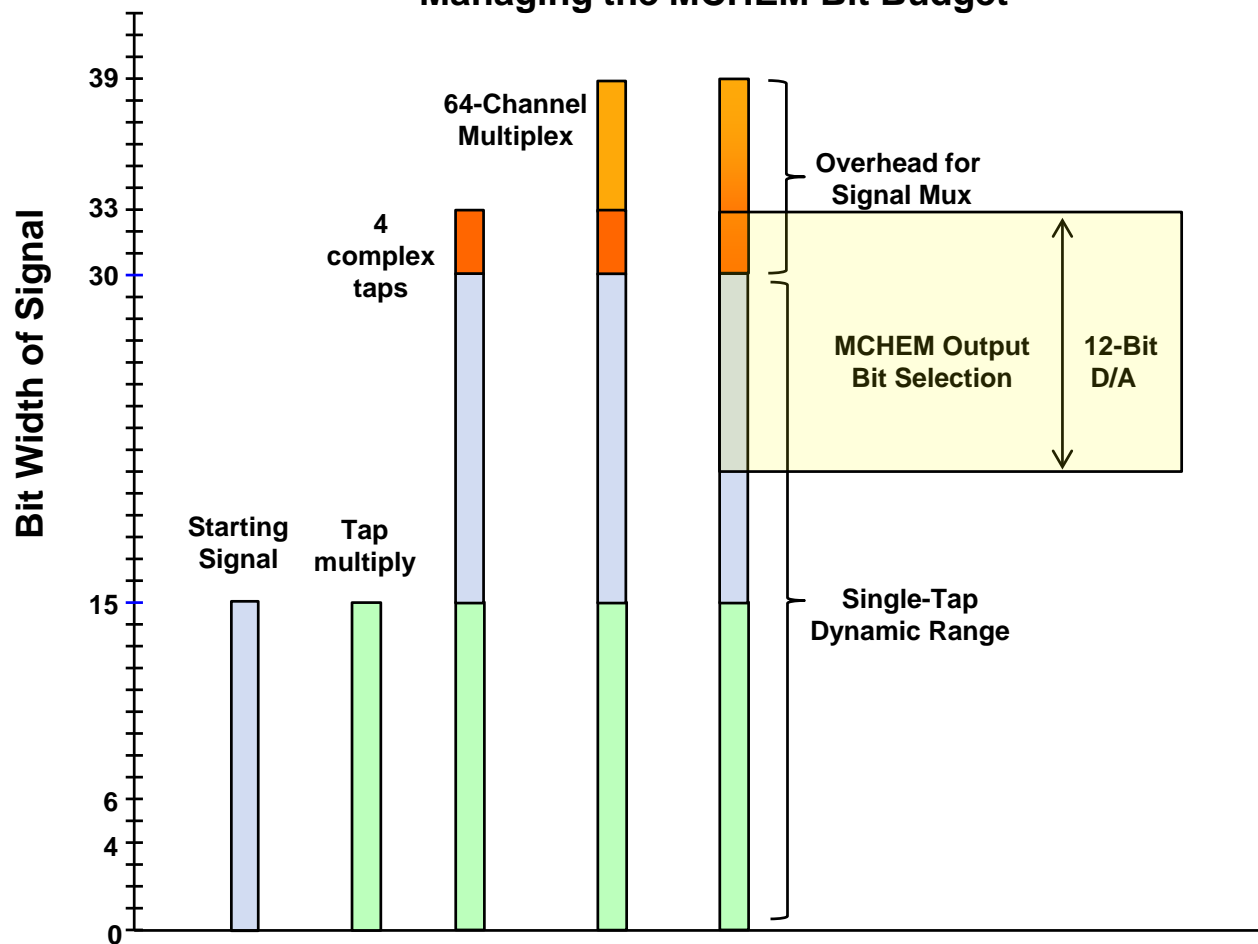




Mapping Concepts to Reality

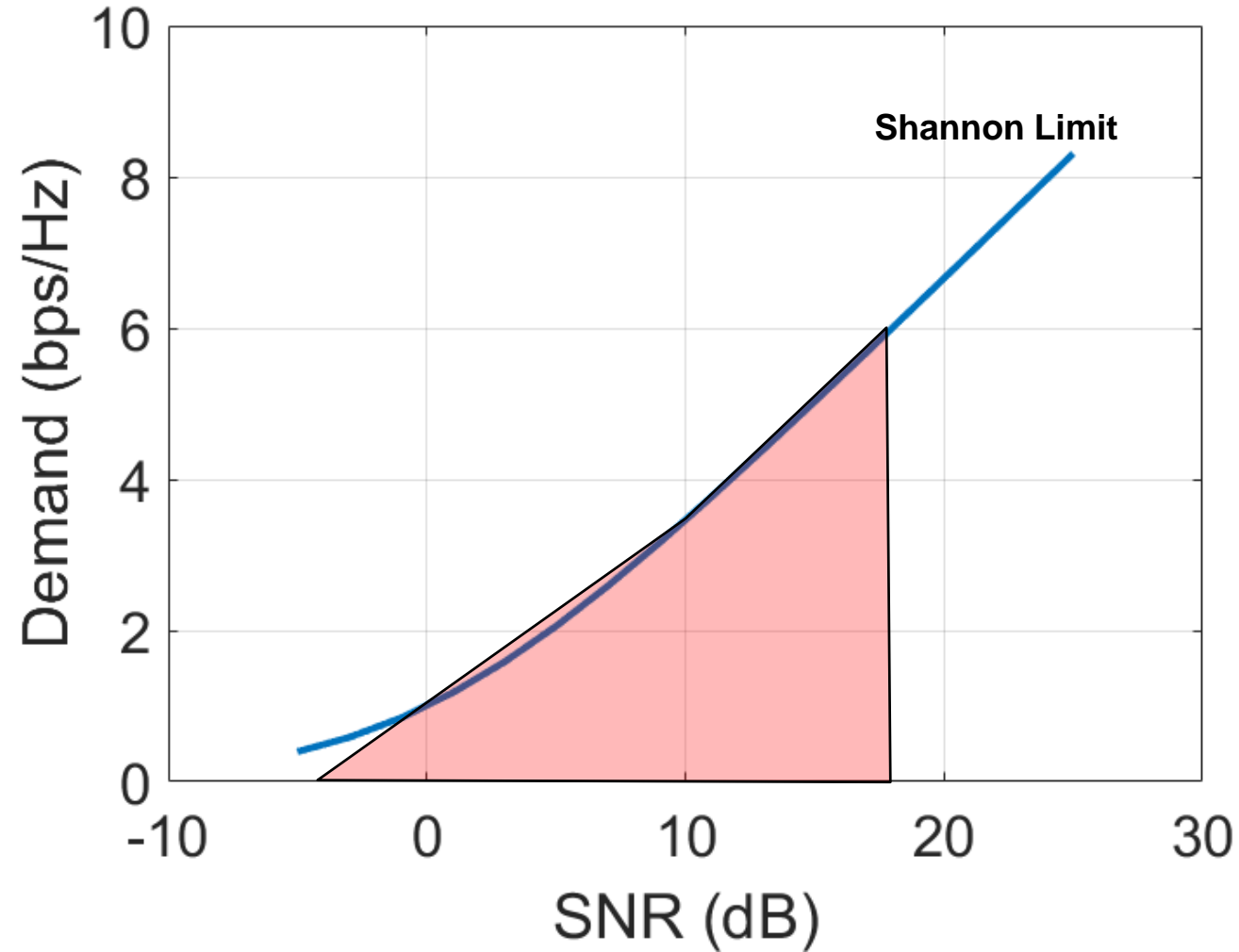
Constraint 2: Dynamic Range

Managing the MCHEM Bit Budget





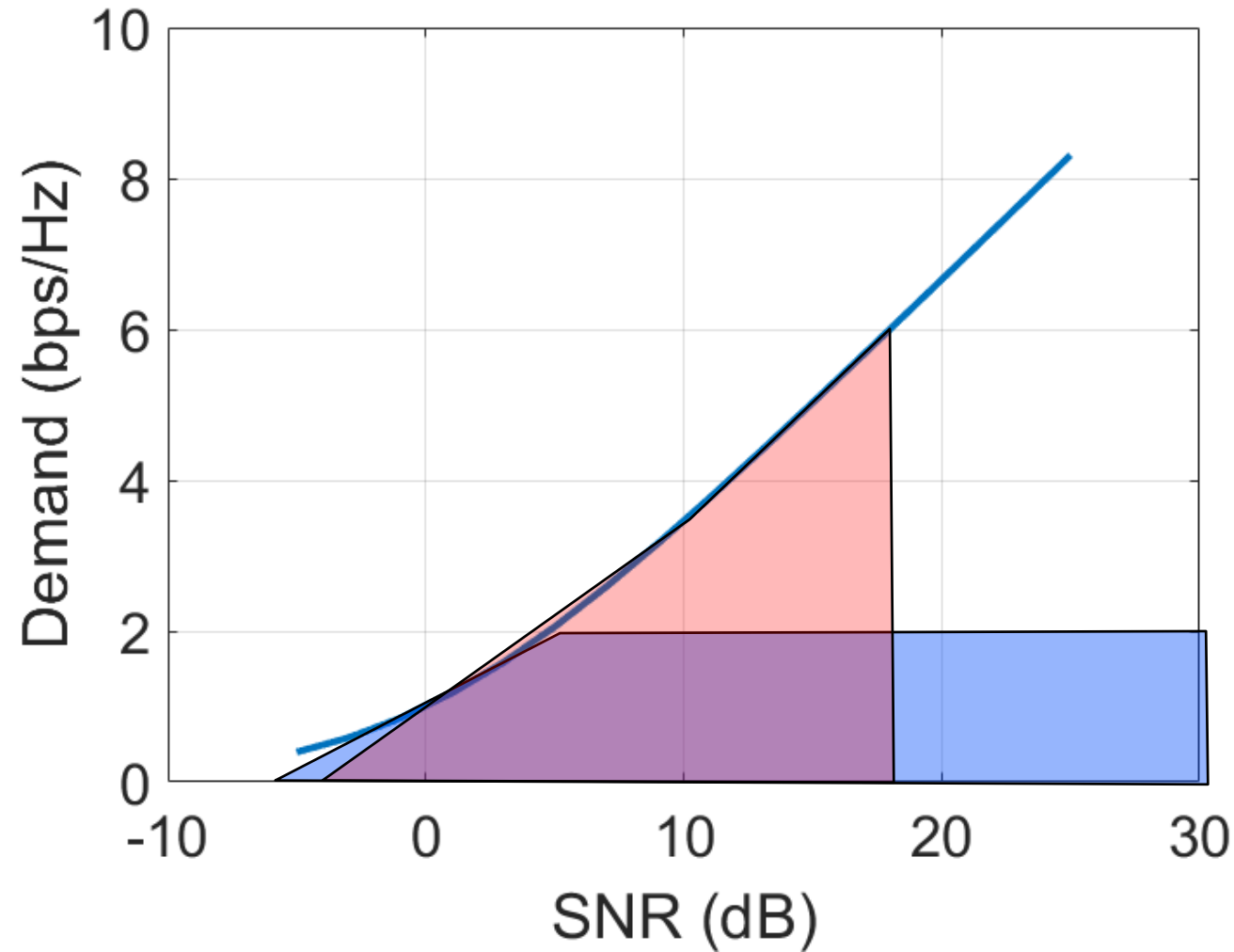
Refining the Target Operating Region



SC2 is fundamentally a “collaborative” challenge: SNR range should bound the advantage of radios with high spectrum efficiencies



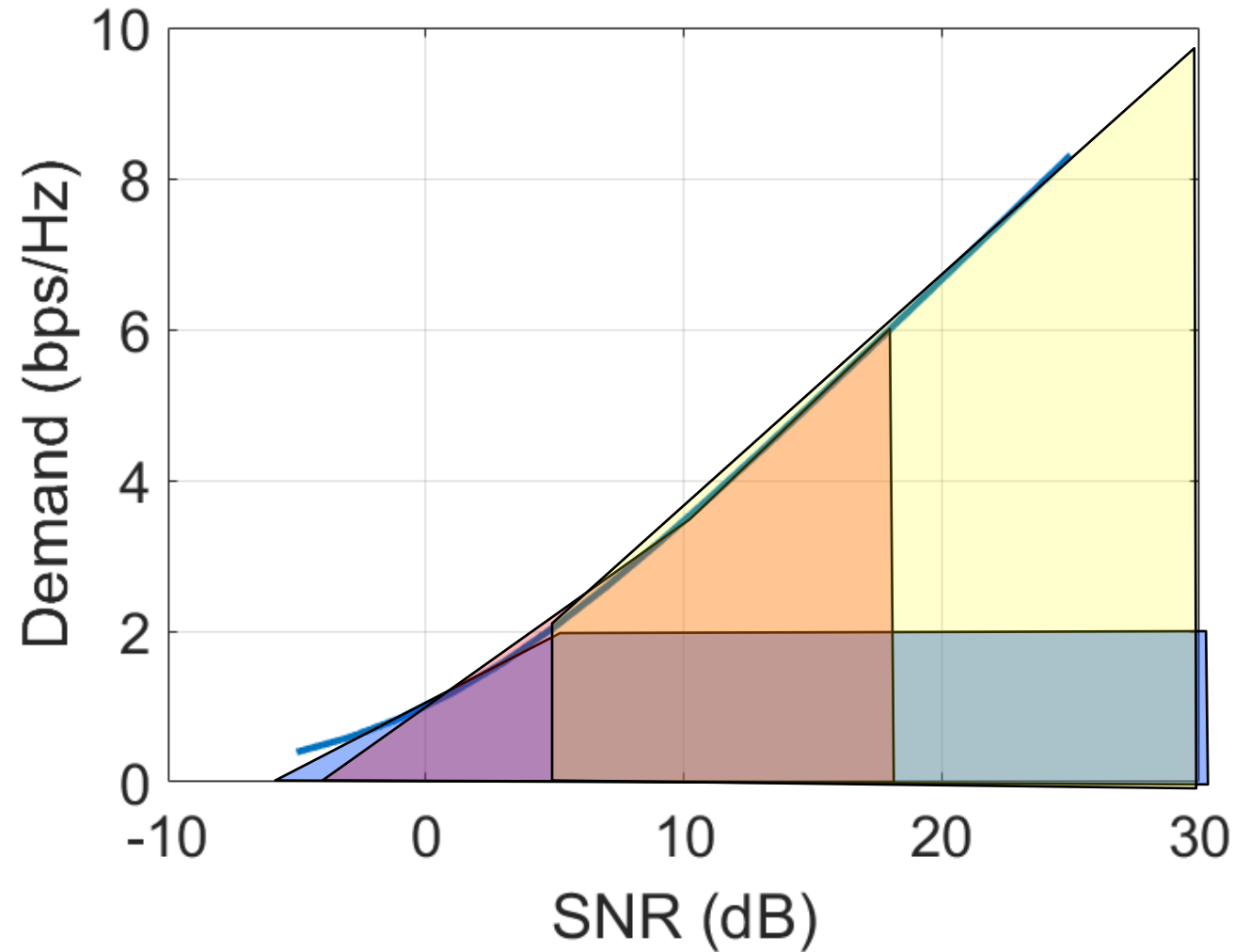
Refining the Target Operating Region



**Demand should be achievable
by radios of moderate
spectrum efficiencies**



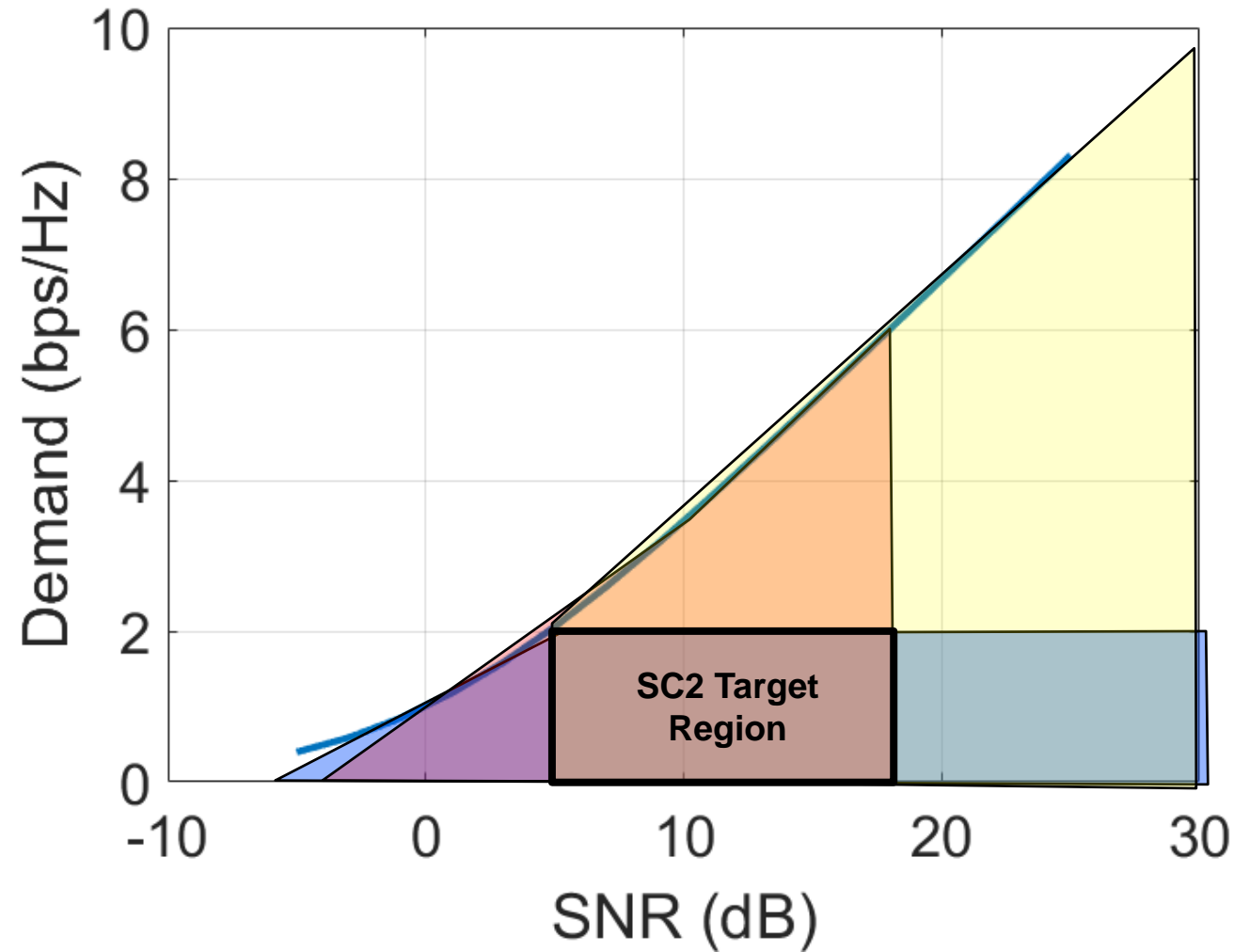
Refining the Target Operating Region



SNR should permit communication with coding schemes of reasonable complexity.



Target Operating Regions for SC2 Scenarios



SC2 Target is the intersection of the above regions.



Getting Down to Brass Tacks

What constitutes an SC2 Scenario?

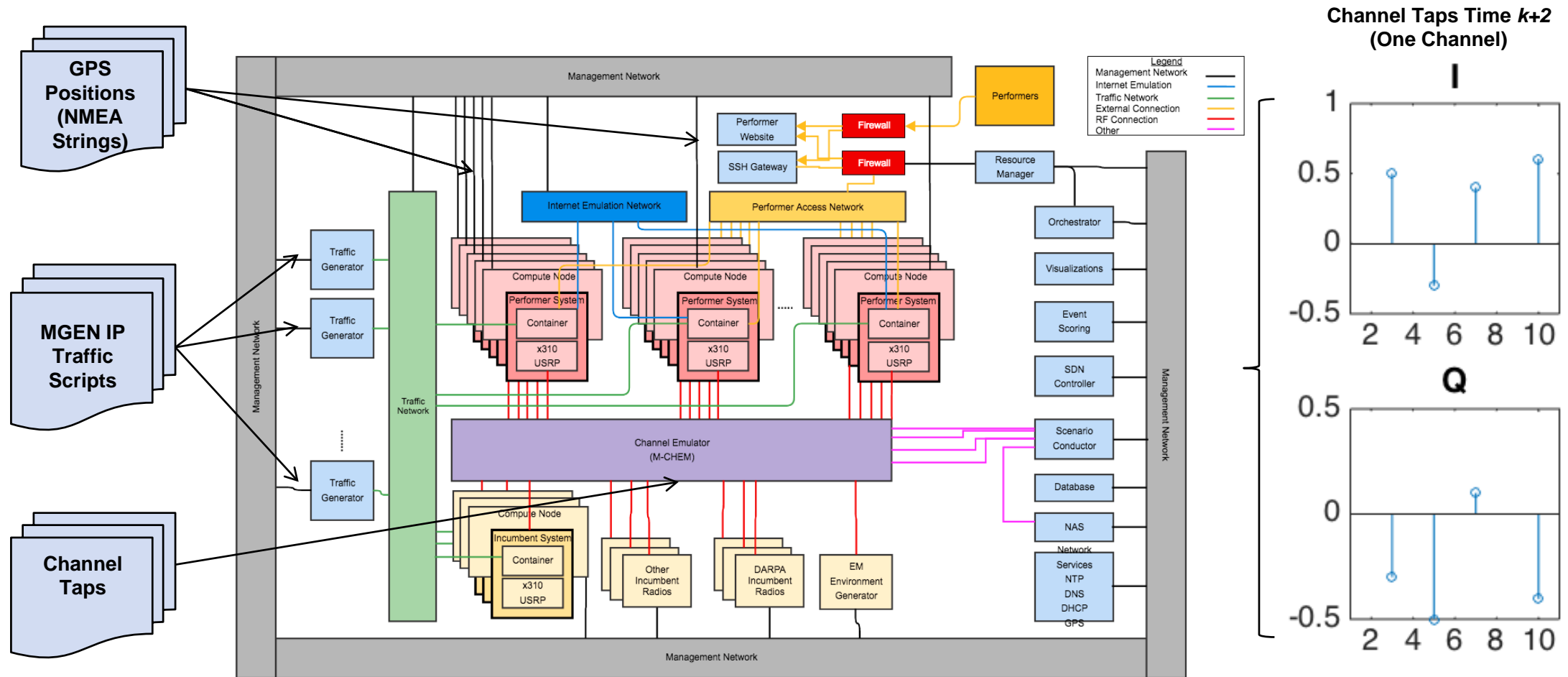


Diagram courtesy of:
Johns Hopkins University / Applied Physics Laboratory



Summary

- **SC2 Scenarios feature collaboration as a key enabler of robust communication in congested spectrum**
- **These Scenarios challenge both Competitor radio and A.I. designs with a combination of complex traffic demands and dynamic RF channel emulation**
- **Key challenge for Scenario developers: digital emulation of the wireless continuum**