Network Planning for Smart Grid

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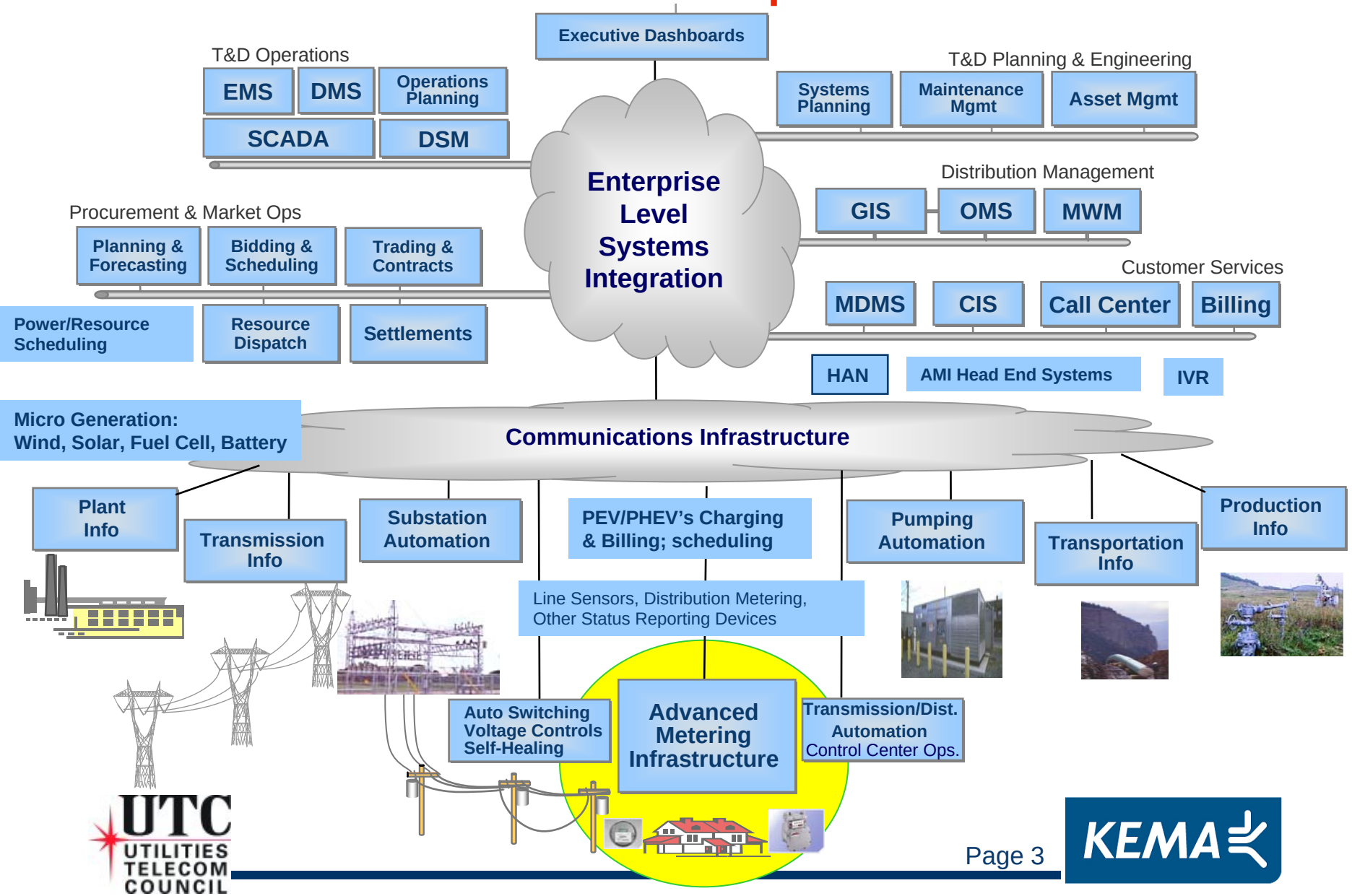
David Boroughs

Objectives

- Smart Grid Architecture Overview
- Network Planning & Dimensioning Aspects
- Network Performance Considerations
- Capacity Planning for Smart Grid

Smart Grid - an Enterprise-Wide Focus.



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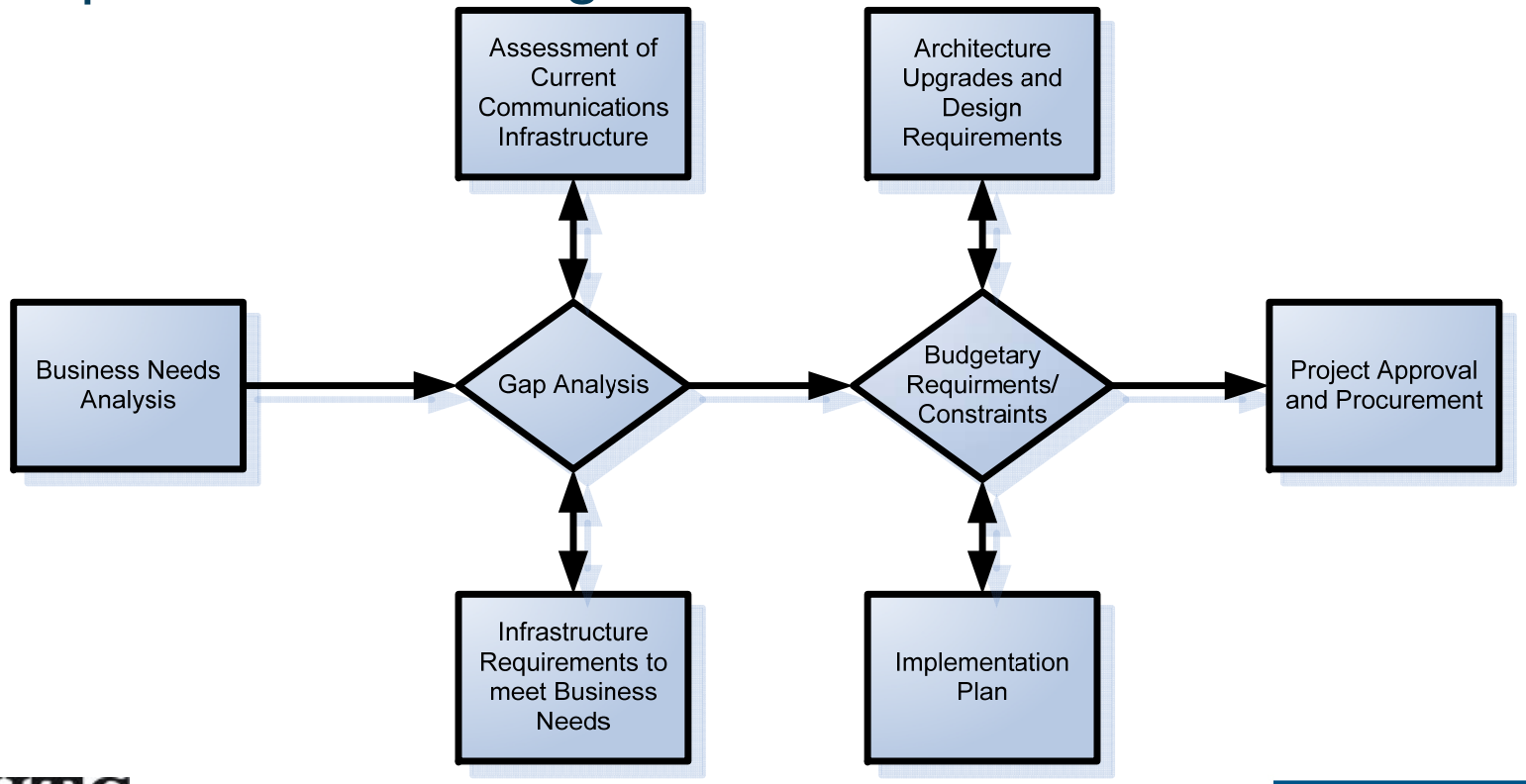
Network Dimensioning for Smart Grid Data

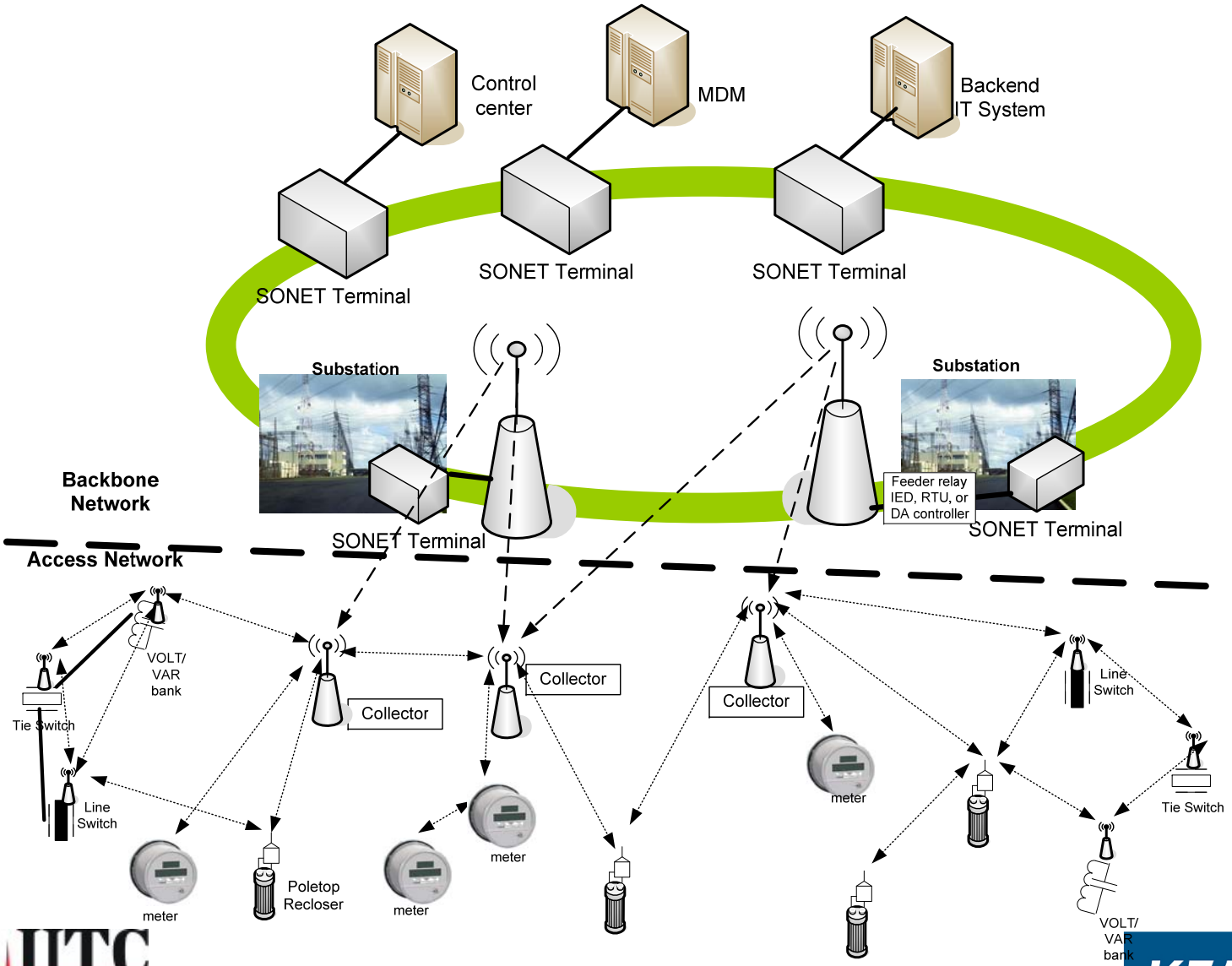
- Review Current Network Infrastructure Capabilities
  - Capability to Support Differing Requirements Based on Criticality of Traffic
  - Network Capacity and Performance
  - Impediments to Meeting Business Objectives/Network Weaknesses
- Required Enhancements to Make Network Infrastructure Supportable
  - Security Requirements For Operational And Non-operational Data
  - Technology Options to Support Requirements

Methodology for Network Planning & Optimization

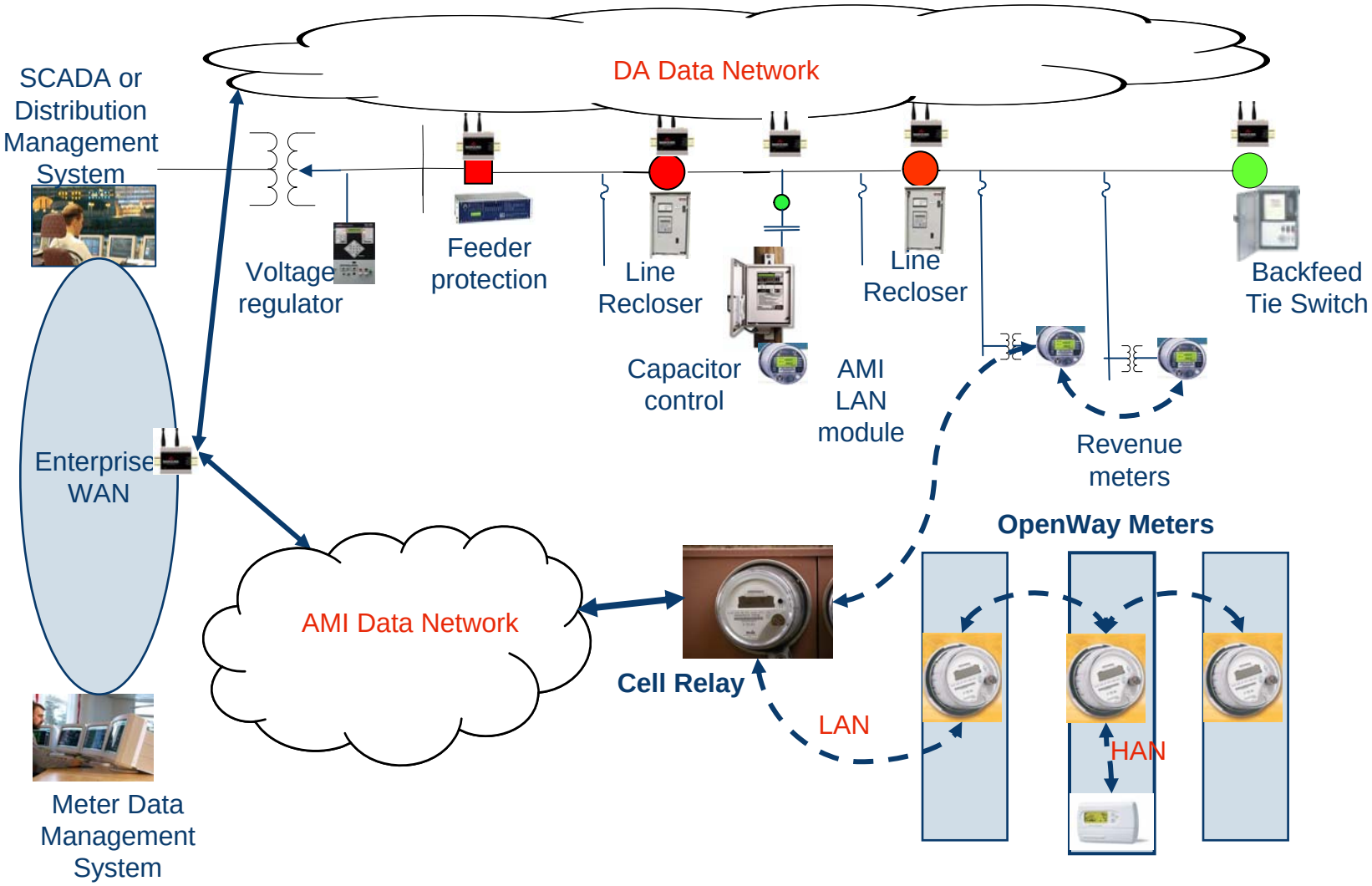
- Communications Architecture Planning, Optimization, Design Process



Backbone and Access Networks



Co-existing Field Networks



Network Performance Components

- Network Availability: Ensuring Network is Available
  - Typically 99.999% Uptime for Operational
  - Excluded Times Of Use Include:
    - Downtime (sometimes excludes maintenance times)
    - Bit-error-rate Degradation Below A Useable Threshold
- Network Latency
  - Maximum Allowable Data Transit Time Through Network
  - Transit time in seconds for operational, minutes for other data type
- Quality of Service (QoS)
  - Critical Data Given Top Priority for Delivery Over Other Data
  - System Management for Optimal Performance
- Capacity Planning
  - System Designed For Adequate Spare Capacity (“Planning Margin”)

Capacity Planning
Network Traffic Modeling

- “Operational” and “Non-Operational”, or “Operational Support” Traffic
- Substation Traffic Load on Backbone Transport Network
- Distribution Automation Load on Access network
- AMI Traffic load on Access Network
- HAN Traffic Load on Access Network
- Overall Combined Traffic effects on Total Network

Sizing of Data Elements for Substation and DA Traffic Analysis

Sizing of individual Data elements

Data Element Size	Bytes
Analog	*16*
Digital	*2*
Event File	65,536
Oscillograph File	8,640,000

Assumes 8 bytes of data and 8 bytes of quality, time, and other attributes - could be less

Event Files	
# of Events	*512*
Bytes/Event	*128*
Kbytes/Event File	65.54

Including event message

It is assumed that the entire SER buffer of 512 events gets uploaded

Oscillograph Data	Transmission Substation
Bytes/Sample	*8*
Samples/Cycle	*10*
Number of Variables	*10*
Number of Cycles	*10800*
Number of Faults	*1*
Overhead Factor	*1*
Kbytes /file	**8640**

Distribution Substation: 25% of transmission **2160**

It is assumed that the entire buffer of 10 Sec. Data need to be uploaded

Typical Substation IED Characteristics for Operational Data Analysis

Typical IED Characteristics

	Operational				Non-Operational				
	# of Analog	# of Digital	Bytes / Scan		# of Analog	# of Digital	# of SOE	# of DFR	Bytes / Upload
			Analog	Digital					
Small IED	*4*	*8*	**64**	**16**	*4*	*8*	*1*		**65,616**
Medium IED	*8*	*16*	**128**	**32**	*16*	*16*	*1*	*0*	**65,824**
Large IED	*16*	*24*	**256**	**48**	*32*	*24*	*1*	*1*	**8,706,096**

Determination of Bandwidth Capacity

- Modeling of Substation Traffic Load on Transport

Typical Transmission Substation

	# of IEDs		Operational									Non-Operational								
			A point	D Point	Total Point Count	Sec / Scan		Accepted Latency (Sec)		Bytes / Scan	Burst Loading/ Sec	A point	D Point	SER	DFR	% of Interest	Sec / Upload Scan	Accepted Latency (sec)	Bytes / Upload	Burst Bytes / Sec
						A	D	A	D											
Small IED	***40***		160	320	480	*6*	*2*	*6*	*2*	3,200	747	160	320	40	0	*30%*	*600*	*600*	2,624,640	1,312
Medium IED	***10***		320	160	480	*6*	*2*	*6*	*2*	1,600	373	160	160	10	0	*30%*	*600*	*600*	658,240	329
Large IED	***10***		640	240	880	*6*	*2*	*6*	*2*	3,040	667	320	240	10	10	*40%*	*600*	*600*	87,060,960	58,041
Total SA	**60**		**1120**	**720**	**1840**	**6**				**7,840**	**1,787**	640	720	60	10		**600**		**90,343,840**	**59,682**
			Equivalent data in kilobits							***62.72***	***14.293***	***Equivalent traffic in megabits***							***722.75***	***0.48***
Comm Overhead		**25%**	Communications Load offered to Network (kbps)								17.9	Communications Load offered to Network (kbps)								596.8

Typical Distribution Substation

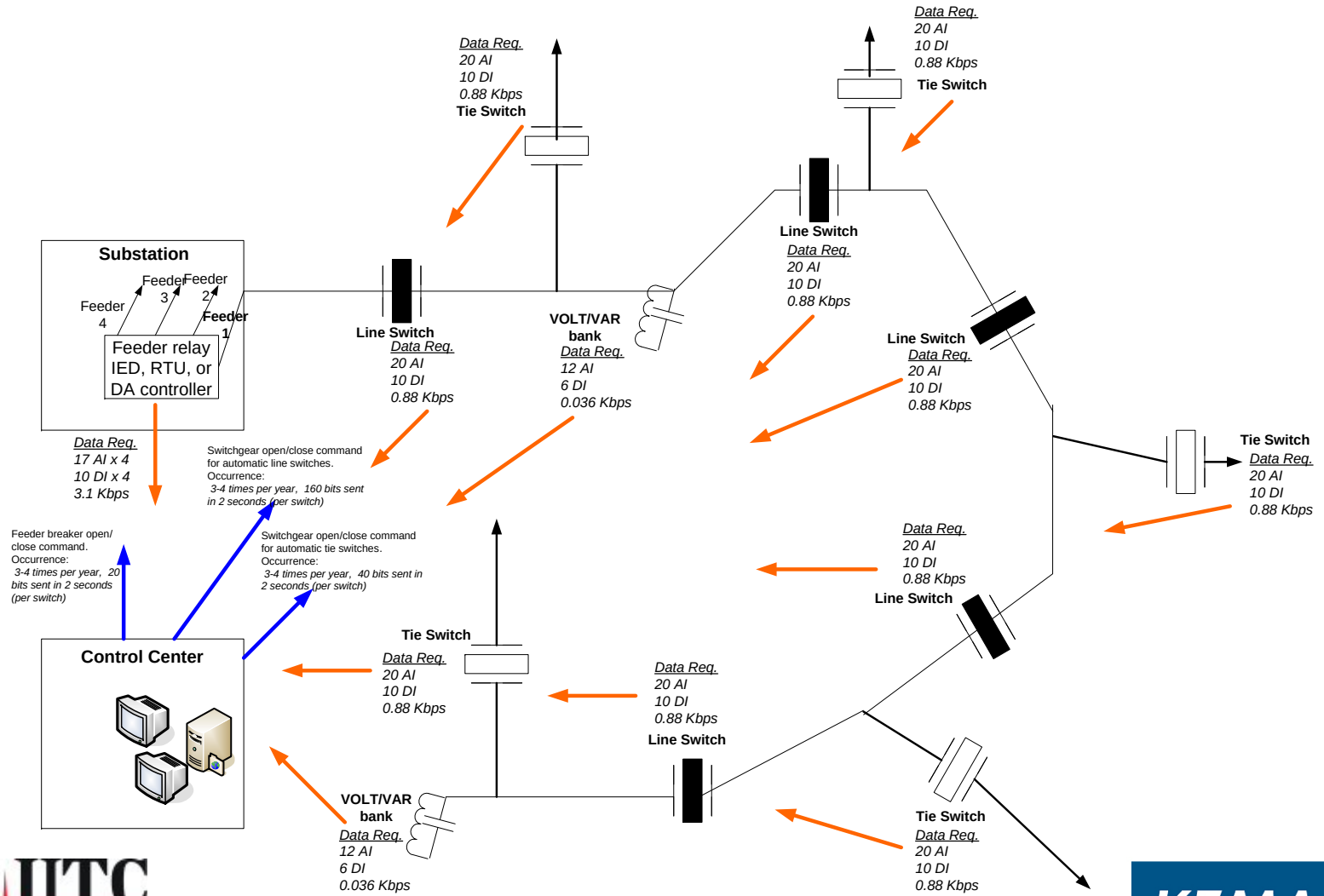
	# of IEDs		Operational									Non-Operational								
			A point	D Point	Total Point Count	Sec / Scan		Accepted Latency (Sec)		Bytes / Scan	Burst Loading/ Sec	A point	D Point	SER	DFR	% of Interest	Sec / Upload Scan	Accepted Latency (sec)	Bytes / Upload	Burst Bytes / Sec
						A	D	A	D											
Small IED	***10***		40	80	120	*6*	*2*	*6*	*2*	800	187	40	80	10	0	*10%*	*1200*	*1200*	656,160	55
Medium IED	***10***		80	160	240	*6*	*2*	*6*	*2*	1,600	373	160	160	10	0	*10%*	*1200*	*1200*	658,240	55
Large IED	***5***		80	120	200	*6*	*2*	*6*	*2*	1,520	333	160	120	5	5	*10%*	*1200*	*1200*	11,130,480	928
Total SA	**25**		**200**	**360**	**560**	**6**				**3,920**	**893**	360	360	25	5		**1200**		**12,444,880**	**1,037**
			Equivalent traffic in kilobits							***31.36***	***7.1467***	***Equivalent traffic in megabits***							***99.56***	***0.008***
Comm Overhead		**25%**	Communications Load offered to Network (kbps)								8.9	Communications Load offered to Network (kbps)								10.4

System Loading Transport Case

200 Transmission Substations
800 Distribution Substations

	# of Substations		Analog Count	Digital Count	Total Count	Operational Data: MBits / Scan	Operational Data: Burst Loading (MBits/Sec)		Non-Operational Data: Mbits / Upload	Non-Operational Data: Burst Loading Mbits / Sec
1.5% of Substations participating										
Transmission	*3*		3,360	2,160	5,520	0.188	**0.04**		2,168	**1.43**
Distribution	*12*		2,400	4,320	6,720	0.376	**0.09**		1,195	**0.10**
Total	**15**		**5,760**	**6,480**	**12,240**	**0.564**	**0.13**	-	**3,363**	**1.53**
Comm Overhead			**25%**	Communications Load (Mbps)		0.16				1.91
3% of Substations participating						**Operational Data**			**Non-Operational Data**	
Transmission	*6*		6,720	4,320	11,040	0.376	**0.09**		4,337	**2.86**
Distribution	*24*		4,800	8,640	13,440	0.753	**0.17**		2,389	**0.20**
Total	**30**		**11,520**	**12,960**	**24,480**	**1.129**	**0.26**	-	**6,726**	**3.06**
Comm Overhead			**25%**	Communications Load (Mbps)		0.32				3.83
5% of Substations participating						**Operational Data**			**Non-Operational Data**	
Transmission	*10*		11,200	7,200	18,400	0.627	**0.14**		7,228	**4.77**
Distribution	*40*		8,000	14,400	22,400	1.254	**0.29**		3,982	**0.33**
Total	**50**		**19,200**	**21,600**	**40,800**	**1.882**	**0.43**	-	**11,210**	**5.11**
Comm Overhead			**25%**	Communications Load (Mbps)		0.54				6.38
10% of Substations participating						**Operational Data**			**Non-Operational Data**	
Transmission	*20*		22,400	14,400	36,800	1.254	**0.29**		14,455	**9.55**
Distribution	*80*		16,000	28,800	44,800	2.509	**0.57**		7,965	**0.66**
Total	**100**		**38,400**	**43,200**	**81,600**	**3.763**	**0.86**	-	**22,420**	**10.21**
Comm Overhead			**25%**	Communications Load (Mbps)		1.07				12.77

Distribution Automation Feeder Requirements



Distribution Automation Traffic Analysis

	Operational			
	# of Analog	# of Digital	Bytes / Scan	
			Analog	Digital
Line switch controller	20	10	400	60
Tie switch controller	20	10	400	60
Volt/VAR	12	6	240	36
Substation Feeder Data	17	10	340	60
Open/Close command-line	0	2	0	12
Open/Close Command-tie	0	2	0	12
Open/Close Cmd-breaker	0	2	0	12

Typical Substation Data to Support Feeder (Data Direction: Substation to SCADA Control ce

			Operational								
	# of Sources		A point	D Point	Total Point Count	Sec / Scan		Accepted Latency (Sec)		Bytes / Scan	Burst Loading/ Sec
						A	D	A	D		
Substation feeder data	4		68	40	108	5	2	5	2	1,600	392
	0		80	0	80	6	2	6	2	-	-
	0		0	0	0	60	60	5	2	-	-
Total Substation Data	4		148	40	188	23.6667				1,600	392
					Equivalent data in kilobits					12.8	3.136
Comm Overhead		25%	Communications Load offered to Network (kbps)								3.92

Typical Feeder Data Load (Data Direction: Feeder to SCADA Control center)

			Operational								
	# of components per feeder		A point	D Point	Total Point Count	Sec / Scan		Accepted Latency (Sec)		Bytes / Scan	Burst Loading/ Sec
						A	D	A	D		
Line switch controller	5		100	50	150	5	2	5	2	2,300	550
Tie switch controller	5		100	50	150	5	2	5	2	2,300	550
Volt/VAR	2		24	12	36	60	60	60	60	552	9
Total Feeder data	12		224	112	336	23.3333				5,152	1,109
					Equivalent traffic in kilobits					41.216	8.8736
Comm Overhead		25%	Communications Load offered to Network (kbps)								11.092

Typical Command data (Data Direction: SCADA Control center to Feeder)

			Operational								
	# of components per feeder		A point	D Point	Total Point Count	Sec / Scan		Accepted Latency (Sec)		Bytes / Scan	Burst Loading/ Sec
						A	D	A	D		
Open/Close Command-Line	5		0	10	10	5	2	5	2	60	30
Open/Close Command-tie	2		0	4	4	5	2	5	2	24	12
Open/Close Cmd-breaker	1		0	2	2	5	2	5	2	12	6
Total Feeder data	8		0	16	16	5				96	48
					Equivalent traffic in kilobits					0.768	0.384
Comm Overhead		25%	Communications Load offered to Network (kbps)								0.480

System Loading DA Case

800 Substations
3000 Feeders

	# of Sources	Analog Count	Digital Count	Total Count	Operational Data: KBits / Scan	Operational Data: Burst Loading (KBits/Sec)
Sources participating POLLING CASE	100.0%					
Substation Data	*800*	118,400	32,000	150,400	10,240.000	**2,508.80**
Feeder Data	*3000*	672,000	336,000	1,008,000	123,648.000	**26,620.80**
Total	**3800**	**790,400**	**368,000**	**1,158,400**	**133,888.000**	**29,129.60**
Comm Overhead		**25%**	Communications Load (Kbps)			36412.00

					Operational Data	
Sources participating RBE CASE	3.0%					
Substation Data	*24*	3,552	960	4,512	307.200	**75.26**
Feeder Data	*90*	20,160	10,080	30,240	3,709.440	**798.62**
Total	**114**	**23,712**	**11,040**	**34,752**	**4,016.640**	**873.89**
Comm Overhead		**25%**	Communications Load (Kbps)			1092.36

					Operational Data	
Sources participating RBE CASE	5.0%					
Substation Data	*40*	5,920	1,600	7,520	512.000	**125.44**
Feeder Data	*150*	33,600	16,800	50,400	6,182.400	**1,331.04**
Total	**190**	**39,520**	**18,400**	**57,920**	**6,694.400**	**1,456.48**
Comm Overhead		**25%**	Communications Load (Kbps)			1820.60

					Operational Data	
Sources participating RBE CASE	10.0%					
Substation Data	*80*	11,840	3,200	15,040	1,024.000	**250.88**
Feeder Data	*300*	67,200	33,600	100,800	12,364.800	**2,662.08**
Total	**380**	**79,040**	**36,800**	**115,840**	**13,388.800**	**2,912.96**
Comm Overhead		**25%**	Communications Load (Kbps)			3641.20

AMI Meter Data Case

Message Type and Direction	Desired Response Time	Estimated Message Size	Estimated Frequency	Estimated Average Data Payload - Backhaul Network	Estimated Average Data Payload - Meter Access Network
		Bytes/ Message	Messages per day	Bytes/day	Bytes/day
System (TDSP to Meter)					
Polling cell relay	<1 hour	0	0	0	
Account Management and Authentication	<1 hour	102	3	306	306
subtotal	**bytes/time period**	**306**	**306**	**0**	
Utility (meter to MDM)					
Tamper	< 5 min	102	0.00034	0	0
Meter status	< 5 min	102	3	306	306
Meter Reads Electric	< 5 min	1000	3	3,000	3,000
Meter Reads Gas	< 5 min	200	3	600	600
Meter Reads Water	< 5 min	200	3	600	600
Meter configuration download	< 5 min	2,500	0.08333	208	208
Meter firmware upgrade	1 day	1,000,000	0	0	0
Remote disconnect	< 60 sec	400	0.00068	0	0
Remote connect	< 60 sec	400	0.00068	0	0
Account Management and Authentication	< 5 min	102	2	204	204
Power Quality	N/A	0	1	0	0
subtotal		**bytes/time period**	**4,919**	**4,919**	**7**
Total Meter Traffic (both ways)			**bytes/time period**	**5,225**	**5,225**
			bits/sec (avg)	**0.48**	**0.48**

HAN Traffic Considerations

- Initial Case-to the HAN

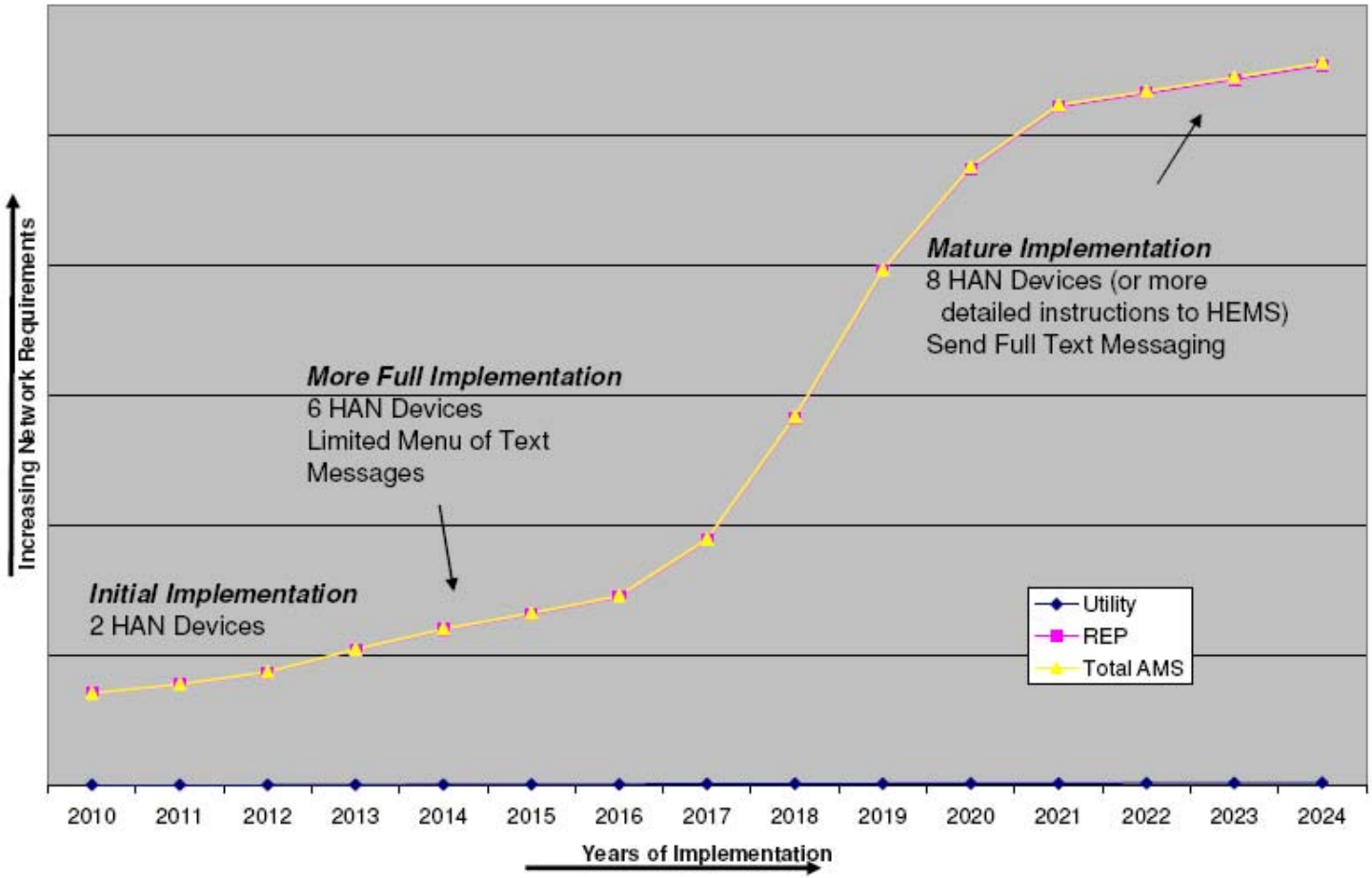
Message Type and Direction	Desired Response Time	Estimated Message Size	Estimated Frequency	Estimated Average Data Payload - Backhaul Network	Estimated Average Data Payload - Meter Access Network	30-Minute Throughput Estimate
		Bytes /Message	Messages per day	Bytes/day	Bytes/day	Bytes/30 min
Retail signals (REP to HAN)						
Direct Load reduction	< 60 sec	102	2	204	204	102
HAN Device (~~6~~ 2 per home) *~~Energy Services~~ Display Device*	< 5 min	204	2	408	408	204
~~Energy Management System~~ ~~Smart Appliance~~ PCT ~~Load Control~~						
Price signaling	< 5 min	200	2	400	400	200
HAN Firmware Update/ Confirmation	N/A	0	0	0	0	
Account Management and Authentication	1 day	102	0.00274			
Subtotal			**bytes/time period**	**1,012**	**1,012**	**506**
			bits/sec (avg)	**0.09**	**0.09**	**2.25**

- Initial Case-From the HAN

Message Type and Direction	Desired Response Time	Estimated Message Size	Estimated Frequency	Estimated Average Data Payload - Backhaul Network	Estimated Average Data Payload - Meter Access Network	30-Minute Throughput Estimate
		Bytes /Message	Messages per day	Bytes/day	Bytes/day	Bytes/30 min
HAN (HAN to REP)						
~~Energy services~~	2	102	0	0	0	0
~~Energy Management Systems (Lighting Control Systems)~~	2	102	0	0	0	
~~Load control~~	2	102	0	0	0	0
PCT	2	102	2	204	204	102
~~Smart appliances~~	3	102	0	0	0	
In -home displays	2	102	2	204	204	102
Sensors (i.e. Gas leak detection, water leaks)	1	102	0.002740	0	0	0.255
			bytes/time period	**408**	**408**	**204**
			bits/sec (avg)	**0.04**	**0.04**	**5.45**

- To be resolved
  - What services provided by the Utility vs Retail provider
  - If retail provider, how will communications be accomplished?

HAN Traffic Could Grow as Customer Acceptance and Applications Increase

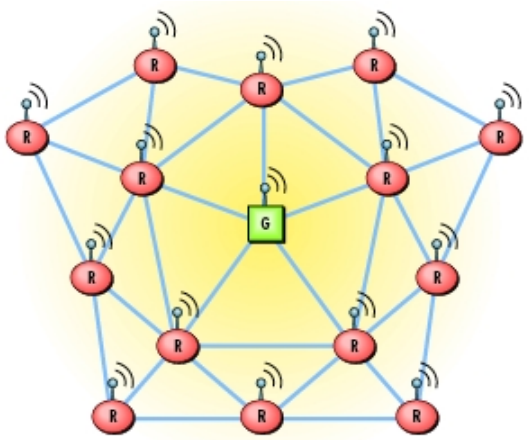


Forecast For Meter and HAN Traffic

	Ntwk to HAN	HAN to Ntwk	Total HAN	Metering (2 way)	Total AMS
Initial Simple Devices	2.25	5.45	**7.70**	0.48	**8.18**
Base Case	8.12	3.63	**11.75**	0.48	**12.24**
Heavy Use Case	37.97	14.97	**52.94**	0.48	**53.42**

(All in Bits per sec)

- If one collector is designed for 5,000 meters
  - 40.9 kbps initial simple devices
  - 61.2 kbps base case
  - 267.1 kbps heavy use case
- If 100 collectors accommodate 500,000 meter
  - 4.09 Mbps total system initial simple case
  - 6.12 Mbps base case
  - 26.7 Mbps heavy use case
- Issues/Considerations
  - Careful design of a collector/meter ratio to ensure no traffic congestion
  - Mesh access network design must ensure system does not choke as data aggregates toward collector
  - Ensure access technology is flexible to support growth
  - HAN data rate function of customer acceptance rates & schemes



Total System Loading Analysis

200 Transmission Substations
800 Distribution Substations

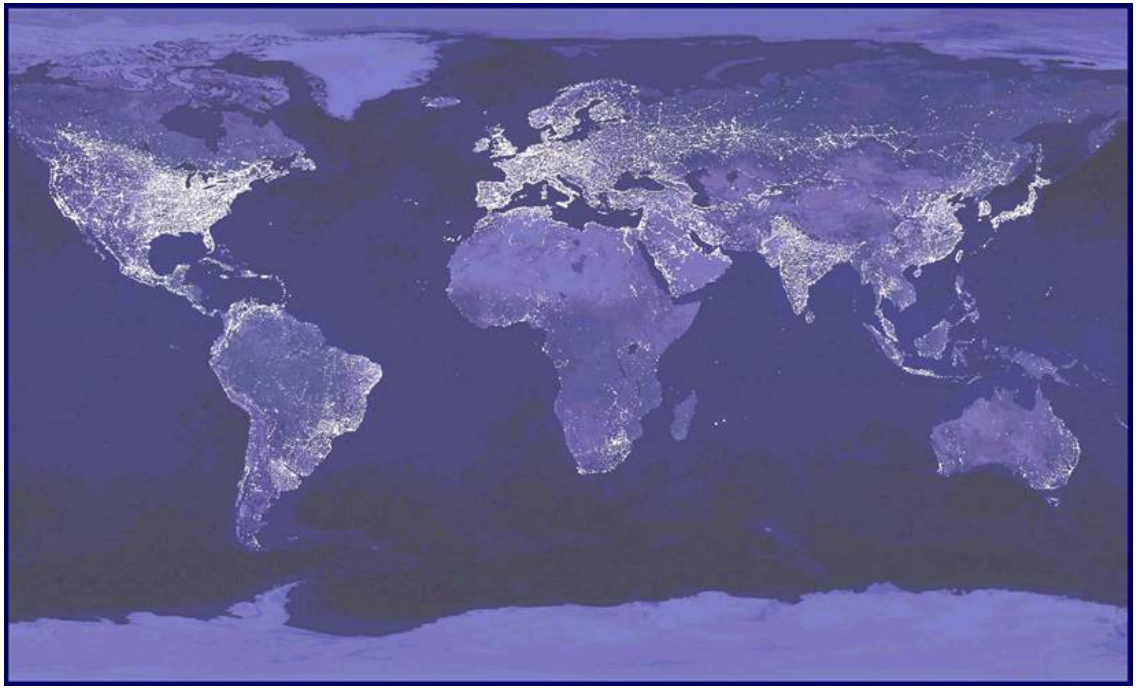
100 collectors
100% HAN customer acceptance base case

	# of Subs or field devices		Analog Count	Digital Count	Total Count	Operational Data MBits / Scan	Operational Data Burst Loading (MBits/Sec)		Non-Operational Data Mbits / Upload	Non-Operational Data Burst Loading Mbits / Sec
3% of Substations participating						Operational Data			Non-Operational Data	
Transmission	*6*		6,720	4,320	11,040	0.38	**0.09**		4,337	**2.86**
Distribution	*24*		4,800	8,640	13,440	0.75	**0.17**		2,389	**0.20**
Substation DA Data	*24*		3,552	960	4,512	0.31	**0.08**			
Feeder DA Data	*90*		20,160	10,080	30,240	3.71	**0.80**			
AMI&HAN Meter Data	*100 collectors,100% customers*			***Base case***			**6.12**			
Total	**144**		**35,232**	**24,000**	**59,232**	**5.15**	**7.25**	-	**6,726**	**3.06**
Comm Overhead			**25%**	Communications Load (Mbps)			9.06			3.83
5% of Substations participating						Operational Data			Non-Operational Data	
Transmission	*10*		11,200	7,200	18,400	0.63	**0.14**		7,228	**4.77**
Distribution	*40*		8,000	14,400	22,400	1.25	**0.29**		3,982	**0.33**
Substation DA Data	*40*		5,920	1,600	7,520	0.51	**0.13**			
Feeder DA Data	*150*		33,600	16,800	50,400	6.18	**1.33**			
AMI&HAN Meter Data	*100 collectors,100% customers*			***Base case***			**6.12**			
Total	**240**		**58,720**	**40,000**	**98,720**	**8.58**	**8.01**	-	**11,210**	**5.11**
Comm Overhead			**25%**	Communications Load (Mbps)			10.01			6.38
10% of Substations participating						Operational Data			Non-Operational Data	
Transmission	*20*		22,400	14,400	36,800	1.25	**0.29**		14,455	**9.55**
Distribution	*80*		16,000	28,800	44,800	2.51	**0.57**		7,965	**0.66**
Substation DA Data	*80*		11,840	3,200	15,040	1.02	**0.25**			
Feeder DA Data	*300*		67,200	33,600	100,800	12.36	**2.66**			
AMI&HAN Meter Data	*100 collectors,100% customers*			***Base case***			**6.12**			
Total	**480**		**117,440**	**80,000**	**197,440**	**17.15**	**9.89**	-	**22,420**	**10.21**
Comm Overhead			**25%**	Communications Load (Mbps)			12.36			12.77

Results of the Process

- A Disciplined And Thorough Approach To Planning, Budgeting, And Implementing Telecommunications Systems As A Strategic Asset Has Benefits
  - Ensures Reliability Of Services
  - Establishes Predictable Budgeting And Cost Control
- Effect Of The Network Planning And Optimization Effort
  - Accommodation Of Enterprise Demands
  - Improved Asset Value
  - Accurate Multi-year Budget Forecasting
  - Implementation Of New Appropriate Technology At The Right Time

Questions??



- David.boroughs@kema.com (703) 631-6912 x40187