


Transitioning the PSTN to IP

Henning Schulzrinne

The retirement of the circuit-switched network

- * What is happening and why does it matter?
- * What are the technical challenges we need to address?
 - reliability & quality
 - public safety (“911”, “112”)
 - numbering & trustable identifiers
 - universal service
 - service stagnation → beyond voice?
 - copper loops → competition, legacy services
- * It's technical + economics + policy



US-centric,
but similar
elsewhere

FCC's Technology Transition Policy Task Force

- The Task Force's work will be guided by the insight that, technological changes do not alter the FCC's core mission, including protecting consumers, ensuring public safety, enhancing universal service, and preserving competition.
- The Task Force will conduct a data-driven review and provide recommendations to modernize the Commission's policies in a process that *encourages continued investment and innovation* in these new technologies, *empowers and protects consumers*, *promotes competition*, and ensures *network resiliency and reliability*.

The three transitions

From		to	motivation	issues
Copper	→	fiber	capacity maintenance cost	competition ("unbundled network elements")
Wired	→	wireless	mobility cost in rural areas	capacity quality
Circuits	→	packets (IP)	flexibility cost per bit	line power

VoIP,
VoLTE

When?

no single transition date!

2013

switching
(core)

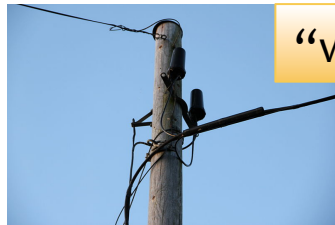
TDM

VoIP

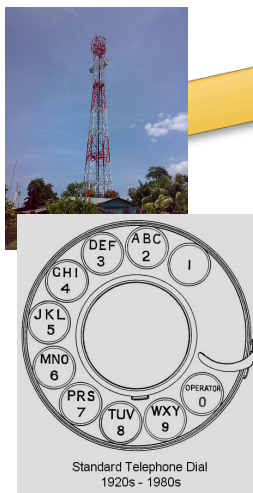


“wireless network is 99% wired”

access



numbering



E.164

human-visible

hidden

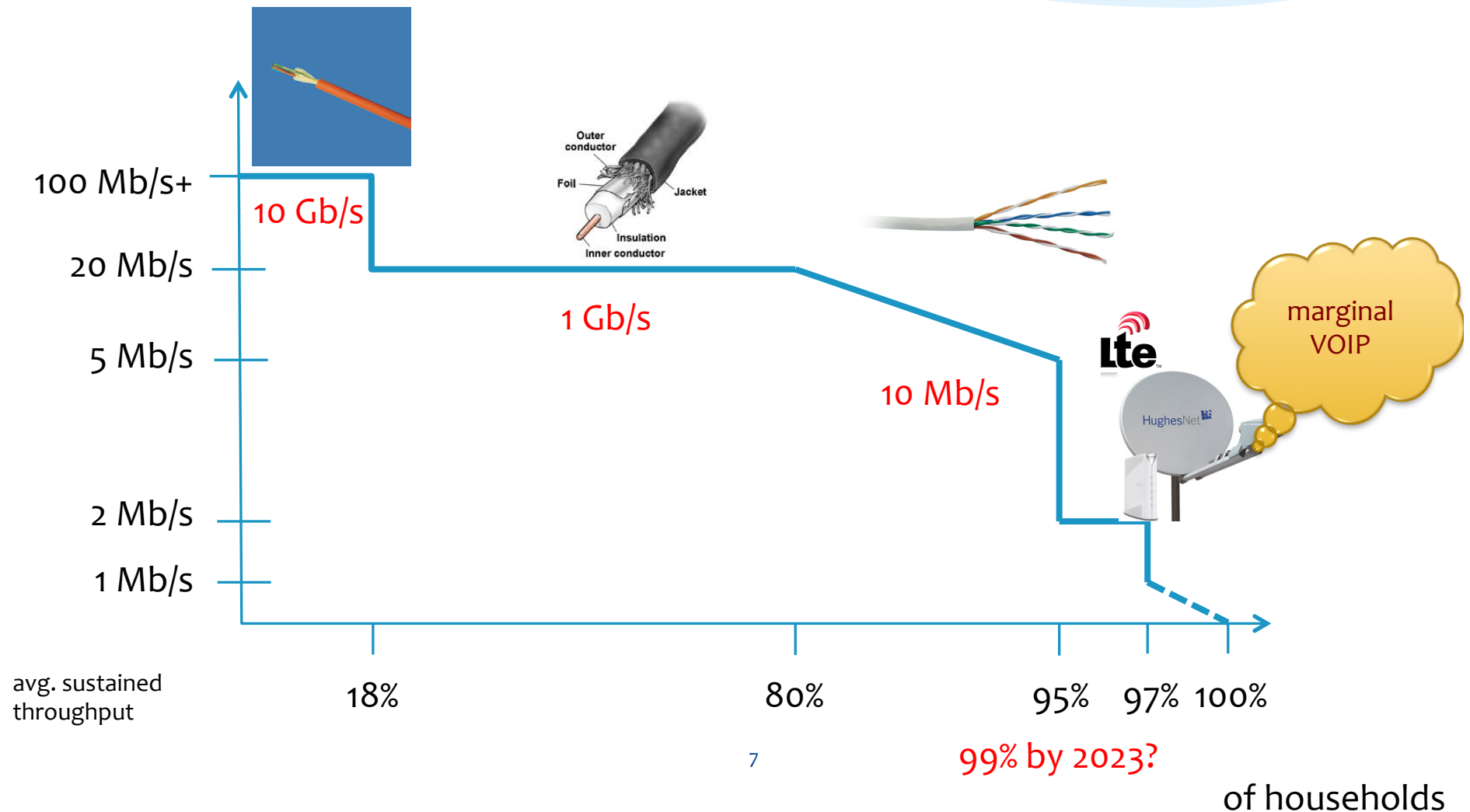
IETF86

The transition of the PSTN

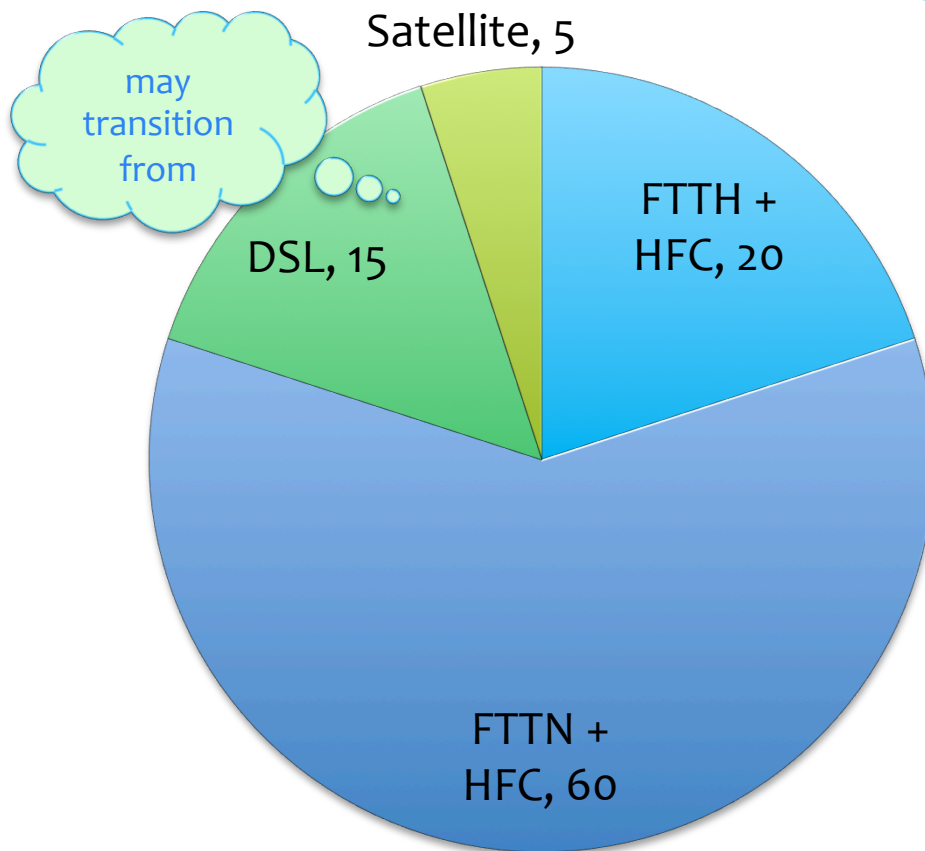
- * User behavior changes
 - more text, less voice
 - video conferencing for personal & business use (telepresence)
 - landline → mobile
 - OTT VoIP (for international calls)
- * Core network technology changes
 - IMS
 - SIP trunking
- * Access and end system changes
 - large PBX all VoIP
 - voice as app
 - WebRTC

Available access speeds

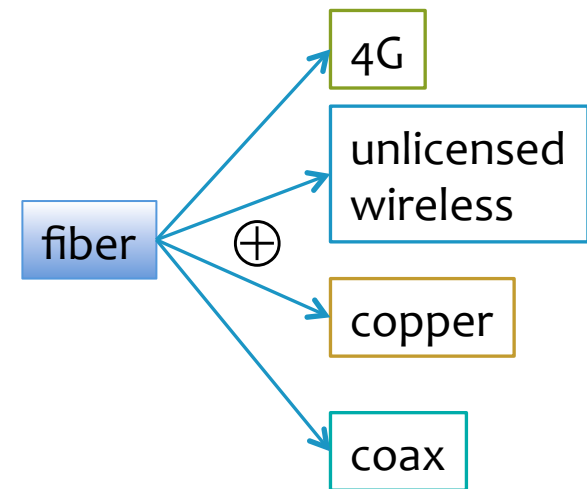
common now – future capability



Access transitions (US)



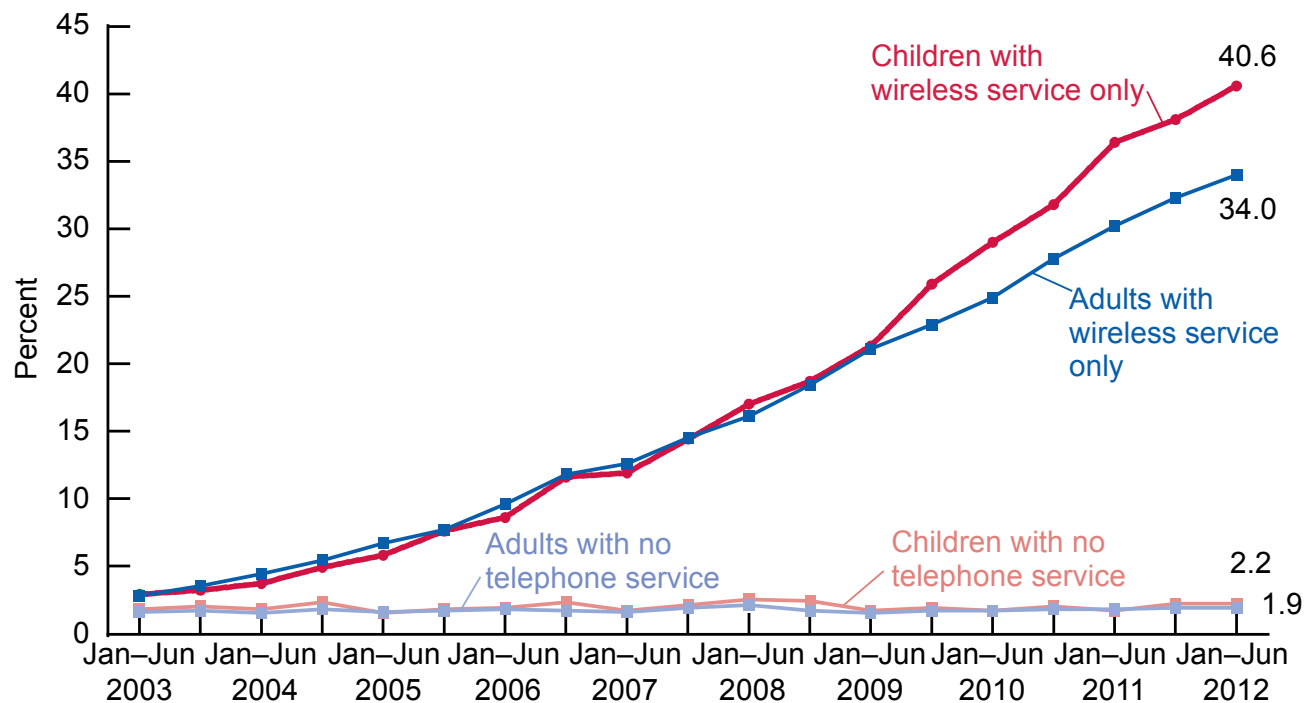
networks go hybrid:



last 500-3000 ft

Landline → mobile

Percentages of adults and children living in households with only wireless telephone service or no telephone service: United States, 2003–2012

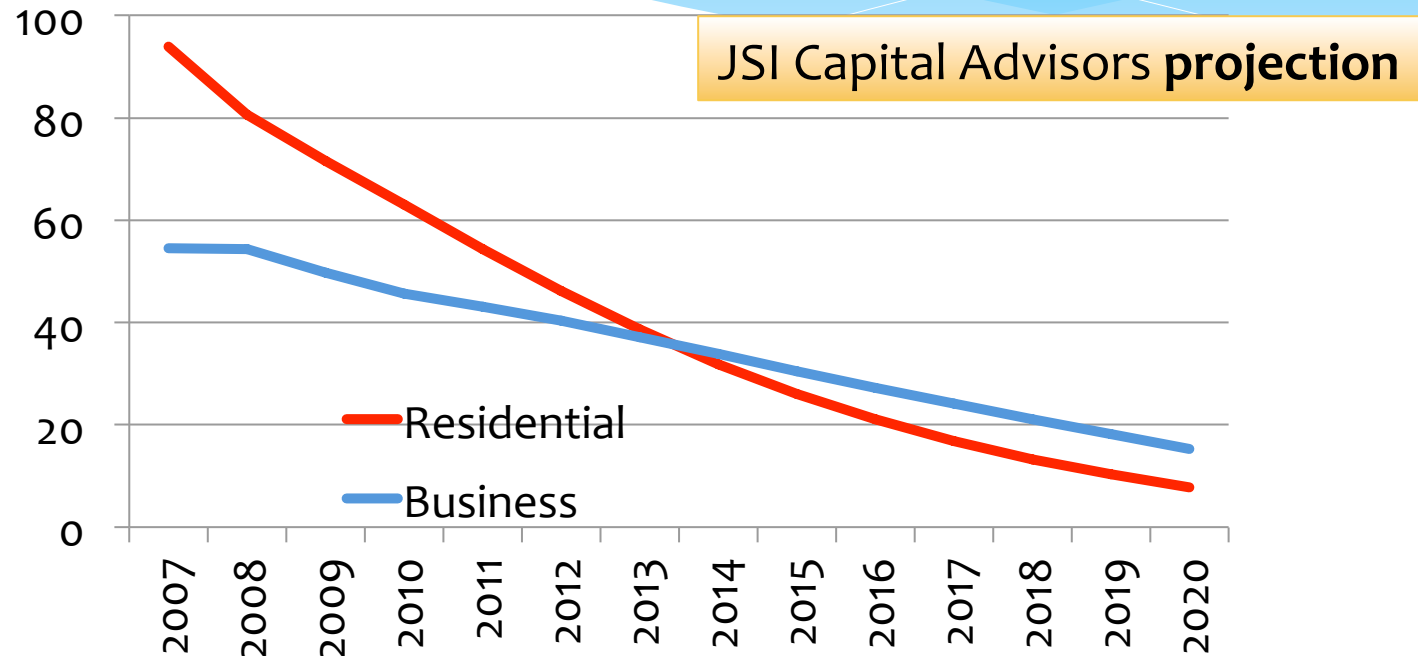


NOTE: Adults are aged 18 and over; children are under age 18.

DATA SOURCE: CDC/NCHS, National Health Interview Survey.

Lines are disappearing, but maintenance costs are constant

voice only
(DSL: 20 M)



per-line monthly
maintenance
cost

\$2.72

\$17.57

voice revenue/line:
\$50

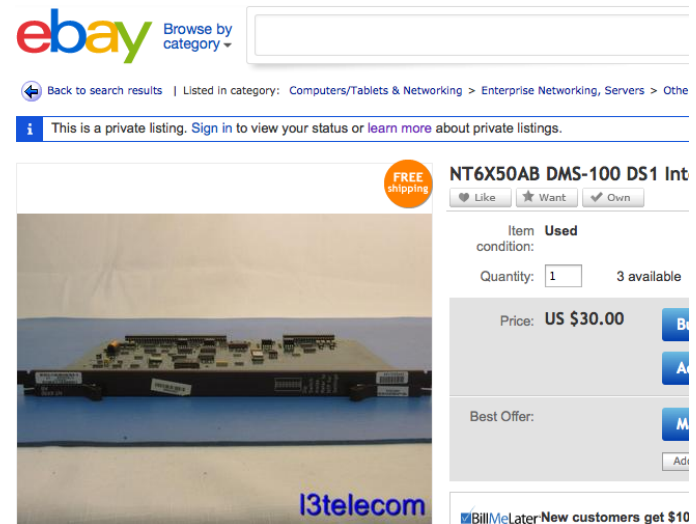
dis

Switches are ageing



Nortel DMS-100

1979



PSTN: The good & the ugly

The good	The ugly
Global Connectivity (across devices and providers)	Minimalist service
High reliability (engineering, power)	Limited quality (4 kHz)
Ease of use	Hard to control reachability (ring at 2 am)
Emergency usage	Operator trunks!
Universal access (HAC, TTY, VRS)	No universal text & video
Mostly private (protected content & CPNI)	Limited authentication Security more legal than technical (“trust us, we’re a carrier”)
Relatively cheap (c/minute)	Relatively expensive (\$/MB)

What are some of the “keeper” attributes?

13

* **Universality**

- *reachability* → global numbering & interconnection
- *media* → HD audio, video, text
- *availability* → universal service regardless of
 - * geography
 - * income
 - * disability
- *affordability* → service competition + affordable standalone broadband

* **Public safety**

- citizen-to-authority: emergency services (911)
- authority-to-citizen: alerting
- law enforcement
- survivable (facilities redundancy, power outages)

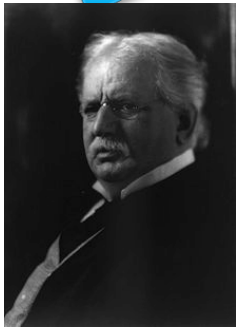
* **Quality**

- media (voice + ...) quality
- assured identity: telephone numbers
- assured privacy (CPNI)
- accountable reliability

initial list – not exhaustive

Universal service

One Policy,
One System,
Universal
Service



T. Vail
(1907)

For the purpose of regulating interstate and foreign commerce in communication by wire and radio so as to make available, so far as possible, to **all the people of the United States**, without discrimination on the basis of race, color, religion, national origin, or sex, a rapid, efficient, **Nation-wide, and world-wide wire and radio communication service** with adequate facilities at reasonable charges, for the purpose of the national defense, for the purpose of promoting safety of life and property through the use of wire and radio communications, ... (47 USC § 151, 1934)

- * Eligible Telecommunications Carriers
- * Carrier of Last Resort (COLR)
- * *Universal Service Fund*

Numbers: Disappearance of the old constraints

The number is part of the problem

- * Geographically assigned (“area codes”)
 - except for VoIP and cellular (US)
- * Separate numbering for SMS, voice, wireless, ...
- * Only traditional carriers can obtain numbers
- * Complex local number portability
 - limited wireless → wireline porting (“wire centers”)
- * Service tied to number → makes 3rd party services difficult

It's just a number

Number	Type	Problem
201 555 1212	E.164	same-geographic different dial plans (1/no 1, area code or not) text may or may not work
#250, #77, *677	voice short code	mobile only, but not all no SMS
12345	SMS short code	SMS only country unclear
211, 311, 411, 911	N11 codes	Distinct call routing mechanism Mostly voice-only May not work for VoIP or VRS
800, 855, 866, 877, 888	toll free	not toll free for cell phone may not work internationally
900	premium	voice only unpredictable cost

Communication identifiers

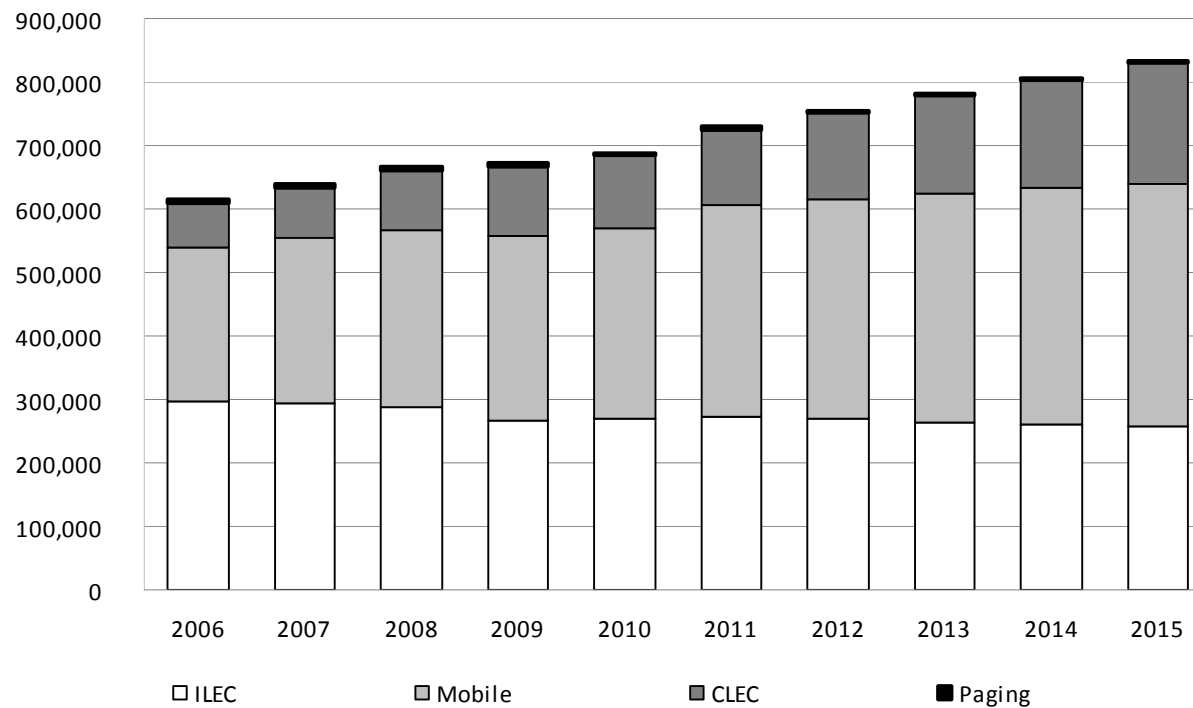
Property	URL owned	URL provider	E.164	Service-specific
Example	alice@smith.name sip:alice@smith.name	alice@gmail.com sip:alice@ilec.com	+1 202 555 1010	www.facebook.com/alice.example
Protocol-independent	no	no	yes	yes
Multimedia	yes	yes	maybe (VRS)	maybe
Portable	yes	no	somewhat	no
Groups	yes	yes	bridge number	not generally
Trademark issues	yes	unlikely	unlikely	possible
Privacy	Depends on name chosen (pseudonym)	Depends on naming scheme	mostly	Depends on provider “real name” policy

Numbers vs. DNS & IP addresses

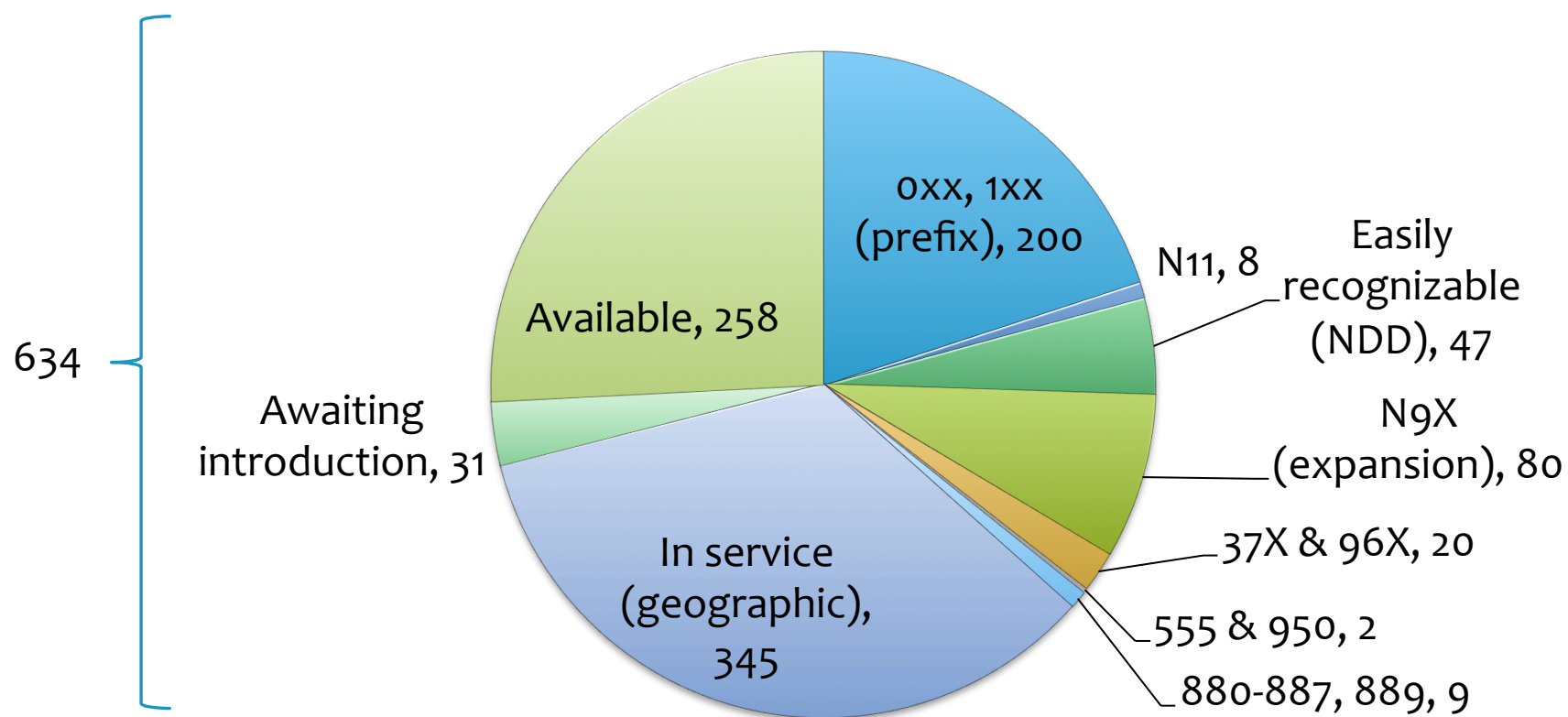
	Phone #	DNS	IP address
Role	identifier + locator	identifier	locator (+ identifier)
Country-specific	mostly	optional	no
# of devices / name	1 (except Google Voice)	any	1 (interface)
# names /device	1 for mobile	any	any
controlled by	carrier, but portability unclear (800#) and geo. limited	any entity, with trademark restrictions	any entity (ISP, organization)
who can obtain?	geographically-constrained, currently carrier only	varies (e.g., .edu & .mil, vs. .de)	enterprise, carrier
porting	complex, often manual; wireless-to-wireline may not work	about one hour (DNS cache)	if entity has been assigned PIAs
delegation	companies (number range)	anybody	subnets
identity information	carrier (OCN), billing name only → LERG, LIDB	WHOIS data (unverified)	RPKI, whois

Number usage

**Number of Assigned Numbers
(Thousands, Source: NRUF, Projections 2011-
2015)**



Area codes (NPAs)



Phone numbers for machines?

212 555 1212 → < 2010



500 123 4567
(and geographic numbers)



500 123 4567
533, 544 →

12% of adults



311,000

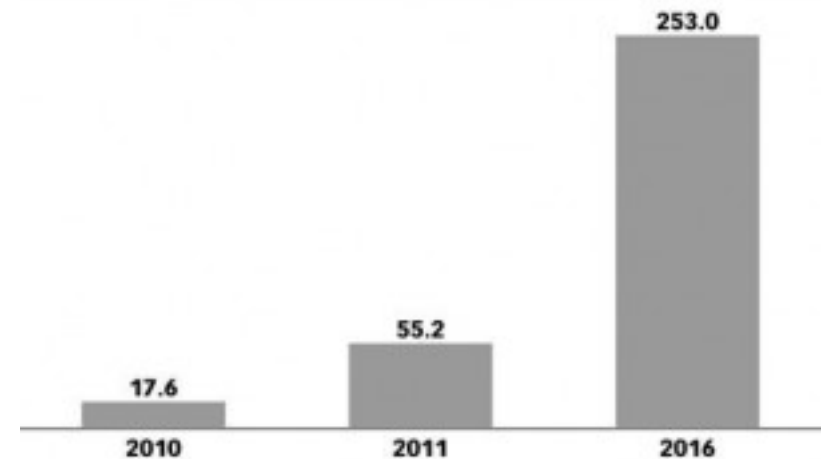


64 mio.



5 mio.

Tablet Shipments Worldwide, 2010, 2011 & 2016
millions of units



Source: Juniper Research, "Tablet & Ereader Evolution: Strategies & Opportunities 2011-2016" as cited in "Viva la Evolution," Sep 21, 2011

132763

www.eMarketer.com

now: one 5XX code a year...
(8M numbers)

10 billion available

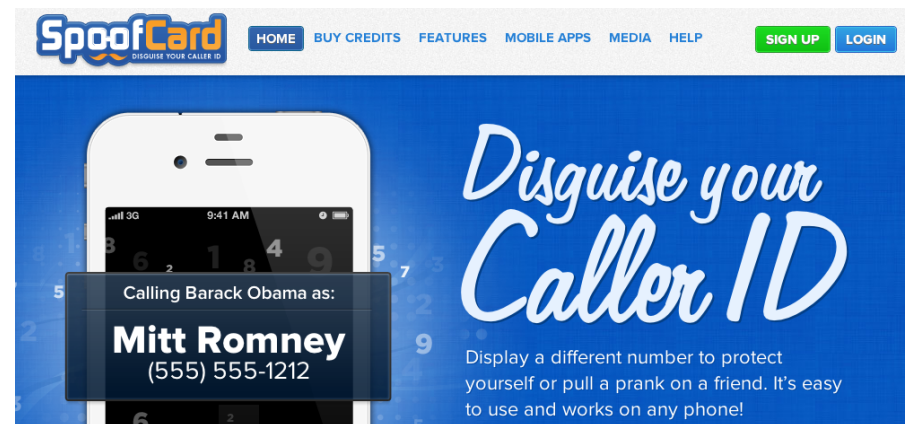
Future numbers

- * Should numbers be treated as names?
 - see “Identifier-Locator split”
 - “multi-homing”
- * Should numbers have a geographic component?
 - Is this part of a region’s cultural identity?

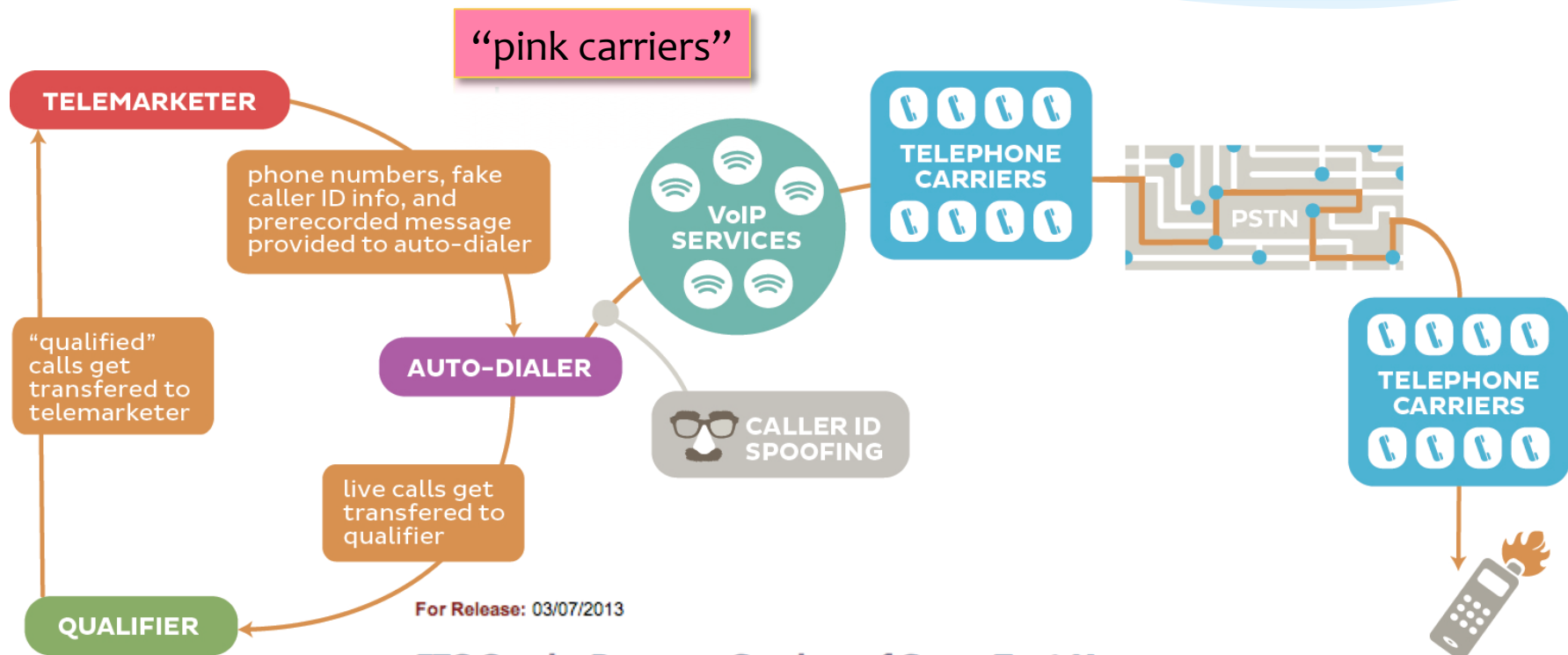


Caller ID spoofing

- * Easily available on (SIP) trunks – can be legitimate
- * Used for vishing, robocalling, swatting, anonymity breaking, ...
- * Caller ID Act of 2009: *Prohibit any person or entity from transmitting misleading or inaccurate caller ID information with the intent to defraud, cause harm, or wrongfully obtain anything of value.*
- * Also: phantom traffic rules



Robocalling



For Release: 03/07/2013

FTC Cracks Down on Senders of Spam Text Messages Promoting "Free" Gift Cards

Defendants Were Responsible for More than 180 Million Spam Text Messages

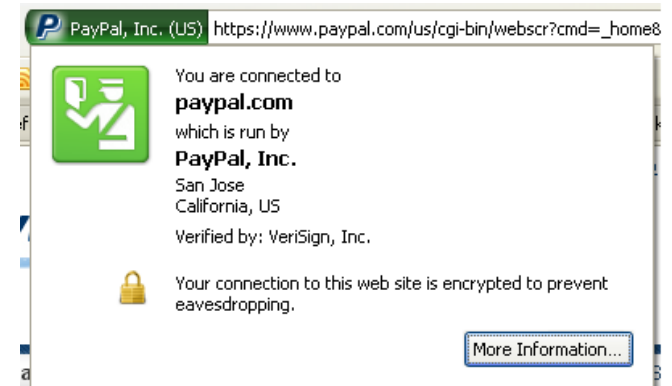
Security (trustworthiness)

- * Practically, mostly about *identity*, not *content*
- * Old model: “trust us, we’re the phone company”
- * Need cryptographically-verifiable information
 - Is the caller authorized to use this number?
 - * not necessarily “ownership”
 - Has the caller ID name been verified?
 - * cf. TLS



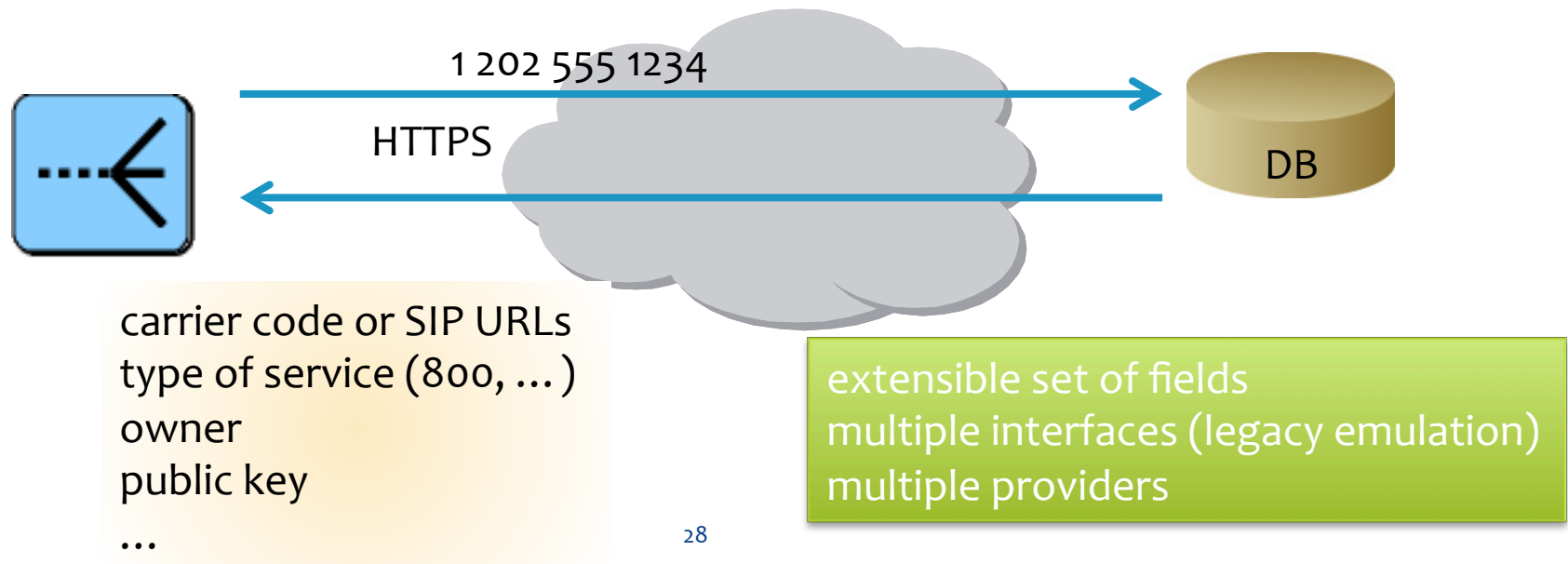
Who assures identity?

- * Web:
 - plain-text → rely on DNS, path integrity
 - * requires on-path intercept
 - X.509 certificate: email ownership
 - * no attributes
 - EV (“green”) certificate
- * PSTN
 - caller ID
 - display name: CNAM database, based on caller ID



Strawman “Public” PSTN database

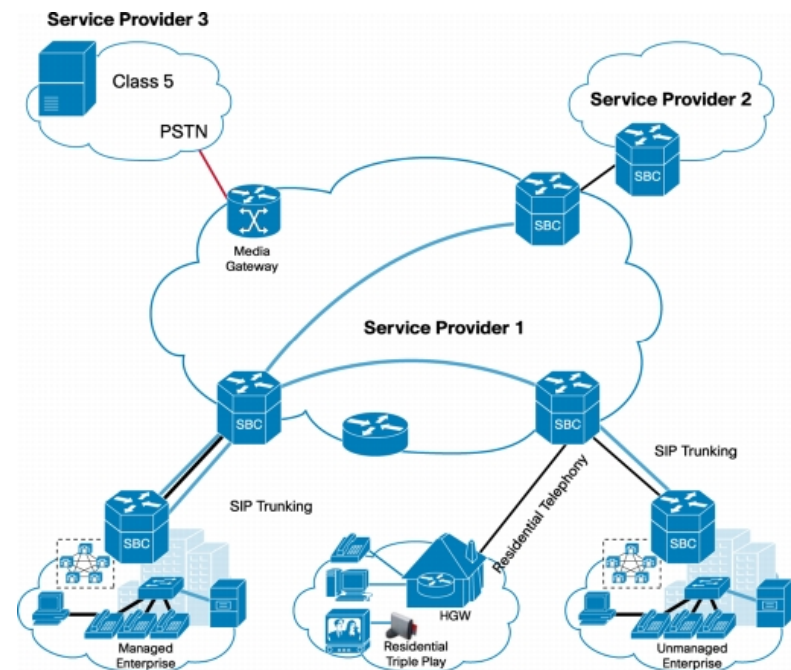
- * Now: LIDB & CNAM, LERG, LARG, CSARG, NNAG, SRDB, SMS/800 (toll free), do-not-call, ...
- * Future:



VoIP interconnection, public safety, universal access

VoIP Interconnection

- * “VoIP interconnection” \neq IP peering
- * Are there technical stumbling blocks?
 - SIP features?
 - Media codecs & conversion?
- * Separation application layer & transport
- * \$0.001 / minute for IP transport (\$0.10/GB) \rightarrow location not relevant



Cisco

Public Safety (NG911 & NG112)

- * Transition to NG911 & NG112 underway
 - NGxxx = all-IP (SIP + RTP) emergency calling
- * Key issues:
 - Indoor location for wireless
 - * location accuracy of 50/150m may not be sufficient
 - * need apartment-level accuracy, including floor
 - * Civic (Apt. 9C, 5 W Glebe), not geo
 - Cost, scaling and transition



More than point-to-point voice

- * VoIP = **V**oice + **V**ideo + **V**ords (text)
 - → Real-time communication as base-level service?
- * Accommodate new media codecs (e.g., AMR)
- * See also “advanced communication systems” in U.S. Communications and Video Accessibility Act (CVAA)
- * Just point-to-point? or multipoint?
- * Services beyond call forwarding → web API model
 - e.g., for robocall prevention

Reliability

- * 5 nines → 5 minutes/year unavailable
- * How do we measure reliability & QoS?
 - E.g., FCC *Measuring Broadband America* project?
 - → IETF LMAP
- * Can we improve power robustness?
 - Circuit-switched: -48V @ 20-50 mA (~ 1 W)
 - e.g., DOCSIS modem consumes ~7W (idle)
 - Li-Ion battery = 2.5 Wh/\$ → 3\$/hour of standby time
- * Can we simplify multihoming to make new PSTN more reliable than old?
 - e.g., cable + 4G



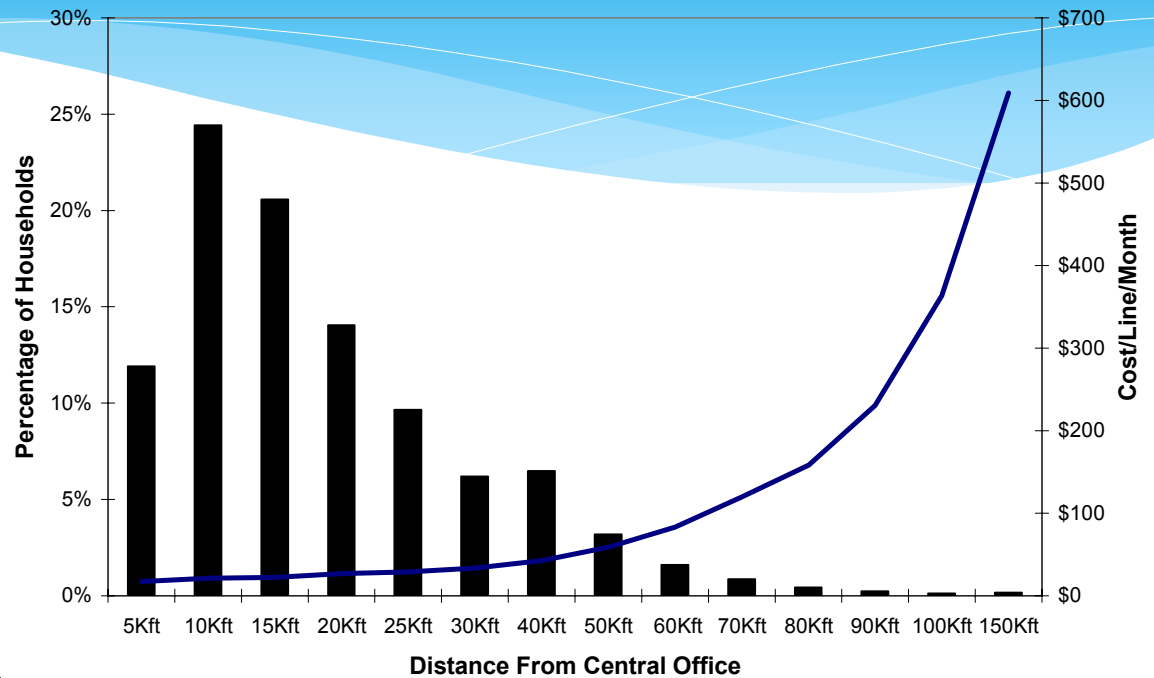
Conclusion

- * Three simultaneous technology transitions:
 - copper → fiber, wired → wireless, circuit → packet
- * But no cut-over date
- * Need to “grow up” quickly
 - no more second network for reporting & fixing things
 - universal service → Internet access for everyone
 - single network → suitable for demanding services
 - life-and-safety network
- * The Internet – your life will depend on it...

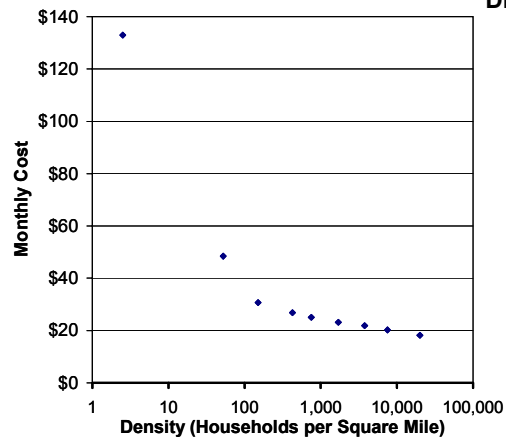


Backup

Cost vs. distance

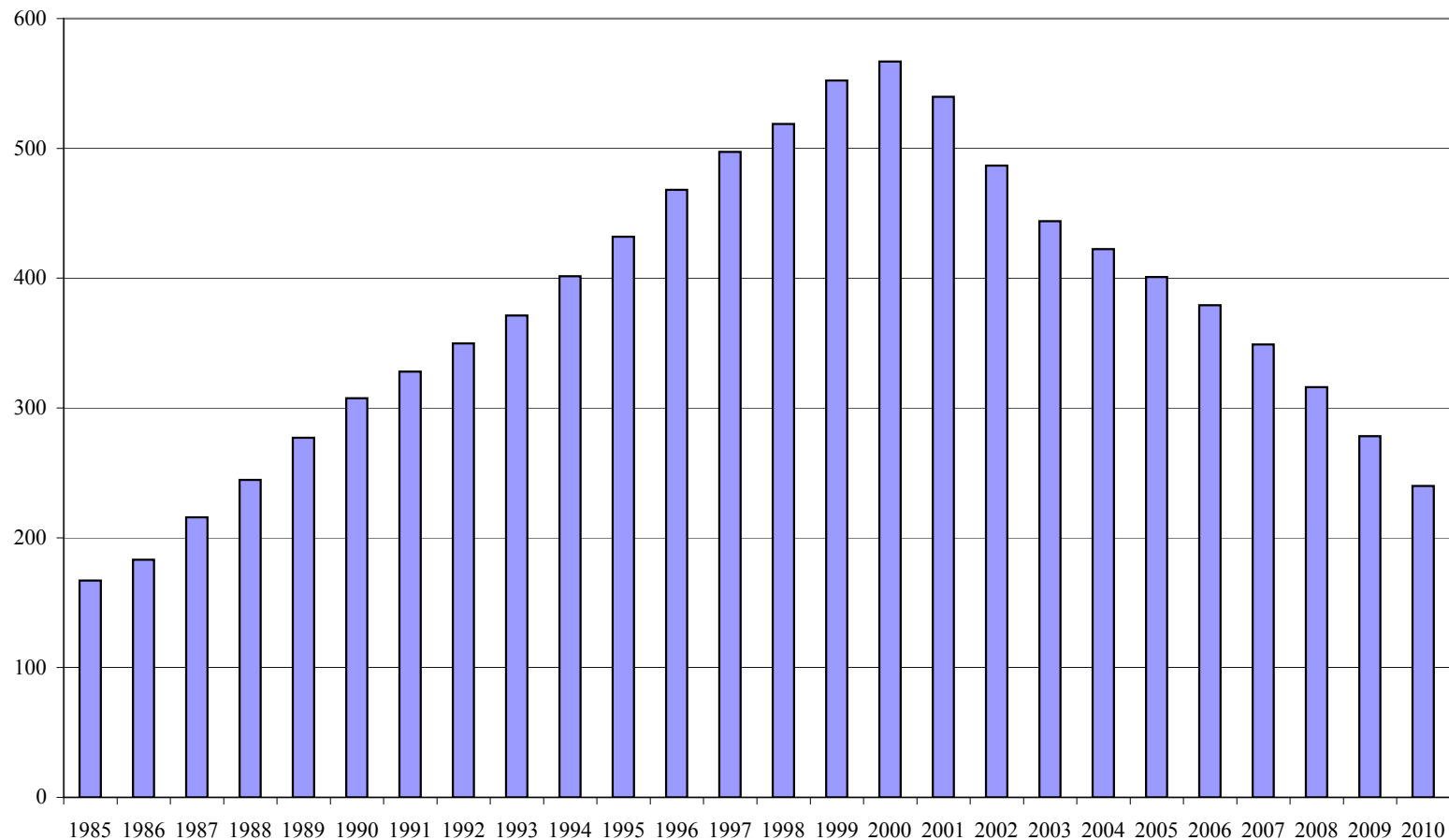


Households per Square Mile	Nationwide Average Cost
0 to 5	\$133.00
6 to 100	\$48.44
101 to 200	\$30.72
201 to 650	\$26.87
651 to 850	\$25.05
851 to 2550	\$23.11
2551 to 5000	\$21.83
5001 to 10,000	\$20.25
> 10,001	\$18.16

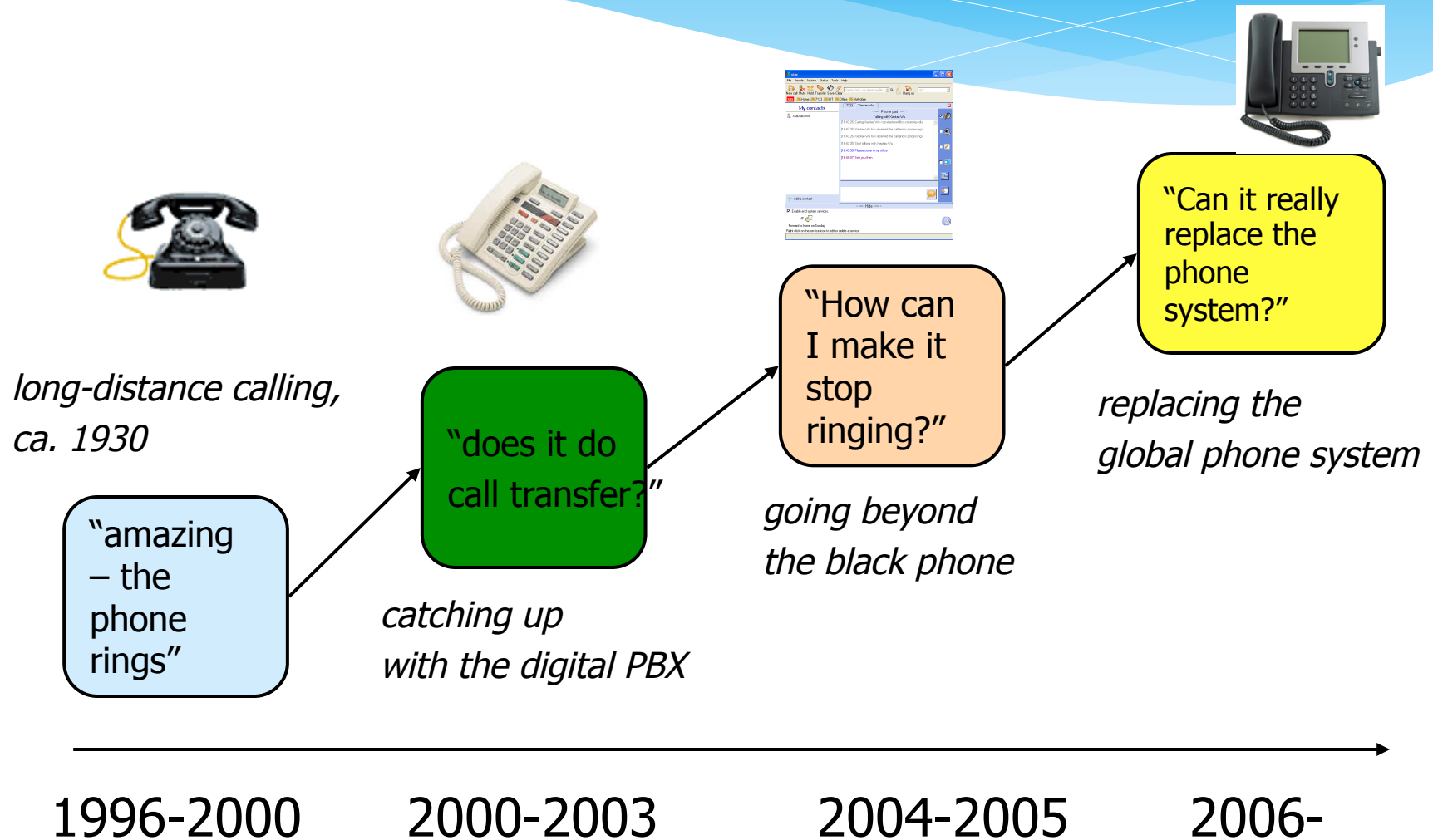


Interstate switched access minutes

Chart 5.1
Interstate Switched Access Minutes of Use for Incumbent Local Exchange Carriers
(in Billions)



Evolution of VoIP





Telephone Social Policies

Universal service (Lifeline, high cost, ...)	Necessary to function (call doctor, call school, ...)
Basic service price regulation	Ensure widespread availability
911	Report emergencies for self and others
Power backup	Ensure emergency communications
Outage reporting	Ensure reliability
Lawful intercept (CALEA)	Phone as tool for criminals
Disability access (ringers, HAC)	Ensure participation in society
CPNI	Phone as private medium

Phone numbers: hoarding

- * How to prevent hoarding?
 - By pricing
 - * DNS-like prices (\$6.69 - \$10.69/year for .com)
 - * takes \$100M to buy up (212)...
 - * 1626: 60 guilders
 - * e.g., USF contribution proposals
 - * \$8B/year, 750 M numbers → \$10.60/year
 - * but significant trade-offs
 - By demonstrated need
 - * see IP address assignment
 - * 1k blocks
 - * difficult to scale to individuals

Philadelphia telecom hoarding toll-free phone numbers

By McClatchy Tribune Newspapers
Posted today at 12:34 p.m.

A small Philadelphia telecommunications company with close ties to an adult-entertainment business has amassed control of more than 1 million toll-free numbers, according to industry sources and a published report.

The toll-free numbers, including 1-800-CHICAGO or 1-800-YOUR-PHILLIES, are used mostly to redirect callers to phone-sex services, the industry observers say.

Inc.'s aggressive acquisition of a massive quantity of toll-free numbers has been controversial in the industry because it has left fewer available for other business purposes.

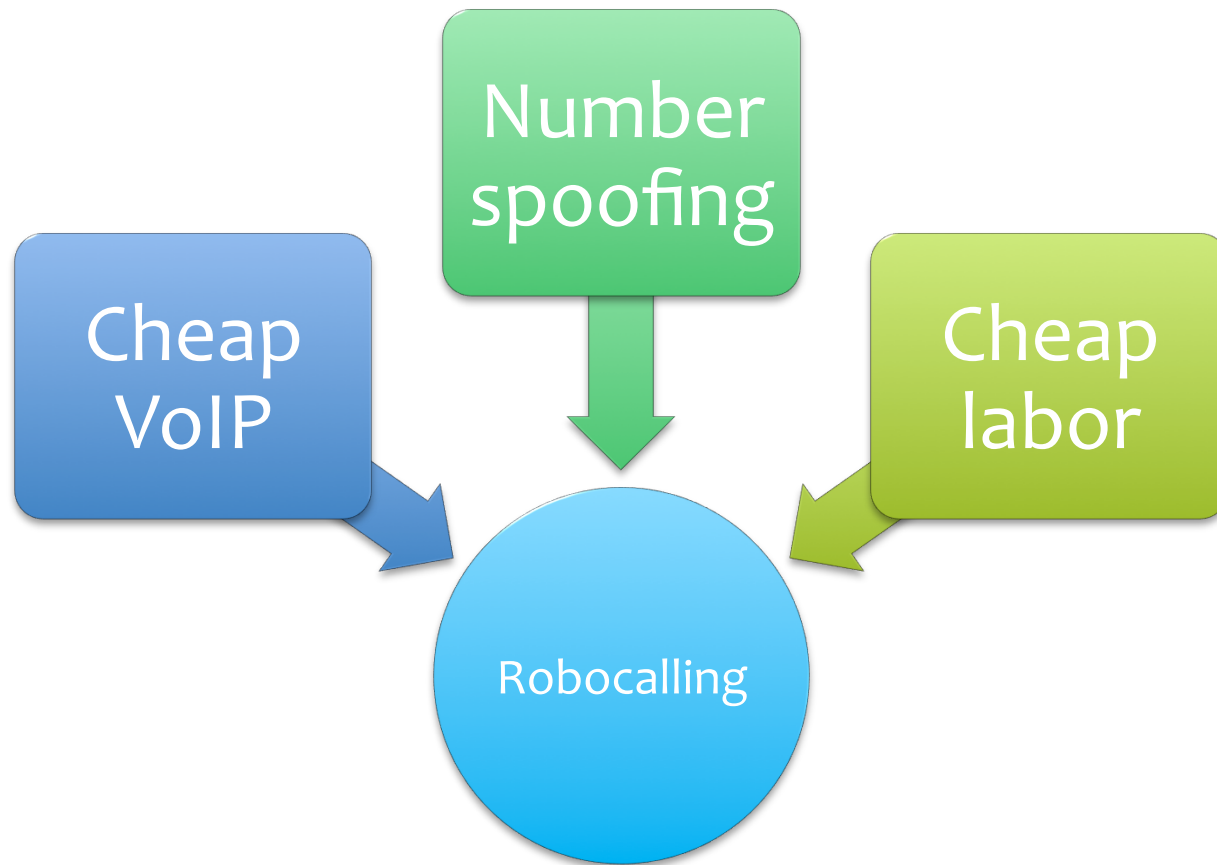
Though there is a public perception that the toll-free business has waned with the proliferation of interactive technologies, officials say the industry continues to grow, with about 30 million toll-free numbers in use.

.com	\$10.69/yr* and lower
.net	\$10.69/yr* and lower
.org	\$10.69/yr and lower
.info	\$3.99/yr Reg \$9.69 LIMITED TIME ¹
.biz	\$10.26/yr and lower

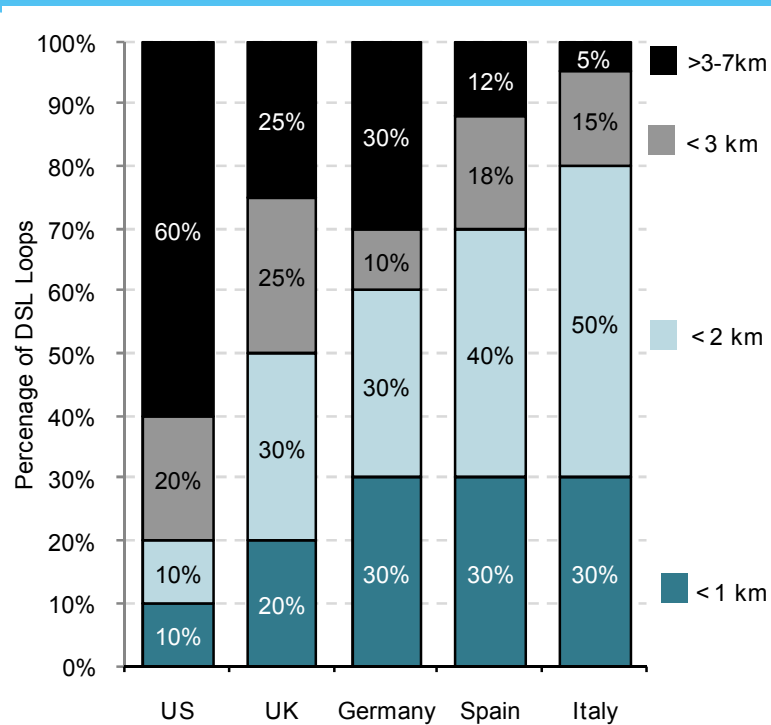
15c/
month

100 million .COM

Robocalls – the enablers



Copper loops



Source: ECTA, Ofcom, Company Reports, Bernstein Estimates

DSL loop lengths

high-speed DSL

Copper loops → large-scale data competition (“unbundled network elements”)

Interconnection

- * PSTN: general interconnection duty
 - requires physical TDM trunks and switch ports
- * VoIP:
 - VPN-like arrangements
 - MPLS
 - general Internet
 - may require fewer points-of-interconnect
 - only relatively small number of IXPs
 - transition to symmetric billing (cellular minutes, flat-rate) rather than caller-pays

FCC USF/ICC reform

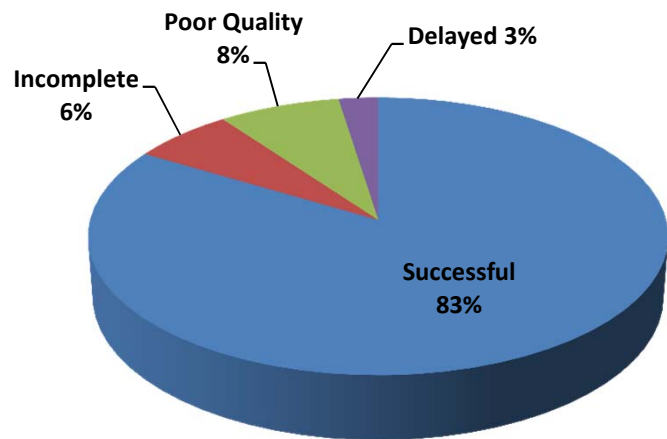
Federal Communications Commission FCC 11-161

42. IP-to-IP Interconnection. We recognize the importance of interconnection to competition and the associated consumer benefits. We anticipate that the reforms we adopt **will further promote the deployment and use of IP networks**, and seek comment in the accompanying FNPRM regarding the policy **framework for IP-to-IP interconnection**. We also make clear that even while our FNPRM is pending, **we expect all carriers to negotiate in good faith in response to requests for IP-to-IP interconnection for the exchange of voice traffic**

- * Technical problem
 - where and how
 - just voice?
- * Money problem
 - who pays for what (conversion, transport, ...)

QoS is not just an Internet problem...

2012 Rural Test Call Results



2012 Non-Rural Test Call Results



7400 test calls to 115 locations

Rural call completion

Service Type	2012 RURAL				2012 NON-RURAL				RURAL Total Issues	NON-RURAL Total Issues
	Attempts	Incomplete Calls	Poor Voice Quality	Delayed Setup*	Attempts	Incomplete Calls	Poor Voice Quality	Delayed Setup*		
IXC	4,037	3.5%	5.3%	2.8%	341	0.6%	1.5%	0.6%	11.6%	2.6%
Wireless	1,162	4.3%	9.0%	1.3%	102	1.0%	8.8%	1.0%	14.5%	10.8%
VoIP-Fixed/Cable	991	6.4%	6.5%	3.0%	84	0.0%	1.2%	2.4%	15.8%	3.6%
VoIP-Nomadic	634	28.4%	21.8%	1.4%	54	0.0%	13.0%	1.9%	51.6%	14.8%
Totals	6,824	6.4%	7.6%	2.5%	581	0.5%	3.8%	1.0%	16.5%	5.3%

* Problems:

- manual error tracing
- complicated least-cost routing arrangements
- termination charge incentives

* Requirements for new PSTN:

- automated call flow tracing
- end-to-end call quality evaluation (→ MBA)