Development Engineering

CSEP 590 B
Community Cellular Networks
Richard Anderson
April 13, 2020

Today

- Announcements
- Kurtis Heimerl – Community Cellular Networks
- Discussions with Kurtis
- Cellular

Announcements

- Discussion Sections – Zoom – Attend one
  - Wednesday: 3:00-4:00 pm
  - Wednesday: 5:00-6:00 pm
- Homework 2, Due April 20.
  - Submit by email
  - Course grade based on 7 of 9 assignments
- Readings:
  - A Longitudinal Study of Local, Sustainable, Small-Scale Cellular Networks, Heimerl et al., Information Technologies & International Development, 11(1), 1–19, 2014.
  - Scaling Community Cellular Networks with CommunityCellularManager, Heimerl et al., NSDI 2019.

Course Schedule

Date	Topic	Lead
April 6	Engineering the Vaccine Cold Chain	
April 13	Community Cellular Networks	Kurtis Heimerl
April 20	Remote Temperature Monitoring	Martin Lukac, Nexleaf
April 27	Election Monitoring	James Long
May 4	Voice Based Social Networks	Aditya Vashistha
May 11	TBD	
May 18	Fintech for Rural Networks	Jenny Aker
May 26	TBD	
June 1	Open Data Kit	Waylon Brunette

Development Engineering

Technological interventions to improve human and economic conditions in low-resource settings

Technical aspects of development engineering
Context for development engineering

How is development engineering practiced in different settings and domain

Development Engineering and Immunization

- Top down environment
  - Policy set from above
  - Country level implementation

World Health Organization

- Where is development engineering going to take place:
  - Big NGOs
  - Technologists
  - Corporate

Cell Phones

- Impact on development

Development Engineering and Cellular Communication

- Global Engineering –
- Central players are going to be telecommunications companies and regulators
  - Tremendous capital required
  - Needed standardization
  - Regulation of spectrum
- Is there an opportunity for Development Engineering in this domain
- Extend connectivity beyond where Telcos can be profitable

Today – Community Cellular Networks

- Kurtis Heimerl
  - Assistant Professor, UW CSE
  - PhD, UC Berkeley (2013)
  - BS, UW CSE (2007)
- Research builds community based systems for rural areas
- UW Early Career Diamond award, MIT TR-35, ISIF Asia Community Network Award, NSDI Community Award

Over to you Kurtis . . .

Additional slides if needed

Communications Infrastructure

Mobile Phones and Development

- Mobile phones have had a dramatic impact worldwide
- Most adults have access to a mobile phone
- Leap frog technology – did not replace land-lines
- Biggest impact is making communication possible where it wasn't previously
- Primarily commercially driven – private or semi-private companies making oodles of money
- Mobile phones have transformed many activities and industries
- Adoption path across different groups has been uneven

Handset Types

- Basic Mobile Phones
- Feature Phones
- Smart Phones



Cell Phone timeline

- 1G: Analog
  - Demonstration 1973. Commercial Launch: Japan 1979 (fully covered in 1984), Nordic countries 1981, USA 1983
- 2G: Digital
  - GSM (Global System for Mobiles)
    - Commercially launched in Finland in 1991.
    - Mandated by European Union in 1987
    - In USA: ATT, T-Mobile
    - Globally Dominant
  - CDMA (Code Division Multiple Access)
    - Commercially Introduced in USA in 1995.
    - Dominated by Qualcomm.
    - In USA: Sprint, Verizon, US Cellular.
- 2.5 G, 2.75 G: Enhanced Digital
  - GPRS (General Packet Radio Service)
  - Enhanced Data Rates for GSM Evolution (EDGE)

Cell Phone timeline

- Marketing terms for multiple technologies
- 3G
  - Faster data speeds
  - Roll out: 2001 Japan, 2001 Isle of Man, 2003 USA
  - Issue in release of new phones
  - Different spectrum than 2G
  - Widespread by 2007
- 4G
  - Long Term Evolution (LTE) standard
  - Even faster data speeds
  - Internet Packet (IP) packet-switched technologies
  - Introduced around 2009 / 2010
- 5G
  - 2018-2020
  - Even faster data speeds

Broadband Applications

Broadband applications using different technologies

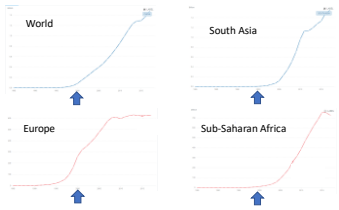
	Fibre	2G		3G**		LTE***
	FTTH	GPRS	EDGE	HSDPA	HSPA+	
Max throughput*	100 Mbps	0.08 Mbps	0.23 Mbps	2 Mbps	56 Mbps	100 Mbps
Email	✓	✓	✓	✓	✓	✓
Basic Internet	✓	*	✓	✓	✓	✓
e-Govt	✓	*	✓	✓	✓	✓
Basic e-Health	✓	*	✓	✓	✓	✓
e-banking	✓	*	✓	✓	✓	✓
Music download	✓	*	*	✓	✓	✓
Video download	✓	*	*	✓	✓	✓
Tele-working	✓	*	*	*	✓	✓
Advanced e-Health	✓	*	*	*	✓	✓
Online gaming	✓	*	*	*	*	✓
High-definition IPTV	✓	*	*	*	*	✓
On-demand multichannel IPTV	✓	*	*	*	*	*

Cell Phone Worldwide Growth

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Afghanistan	0	0	0	1	2	5	10	18	29	37	35	46	50	53	56	58	62	67
Australia	45	58	65	73	83	91	96	101	104	102	102	106	107	108	107	108	110	113
Canada	28	34	38	42	47	53	57	61	66	70	76	78	79	80	81	83	85	86
China	7	11	16	21	25	30	35	41	48	55	63	72	81	89	93	92	97	105
Germany	59	69	72	79	87	97	105	118	130	130	109	112	114	123	122	118	126	129
India	0	1	1	3	5	8	14	20	29	43	61	72	68	69	73	76	85	87
Kenya	0	2	4	5	7	13	20	30	42	48	60	66	70	71	73	80	80	86
Mali	0	0	0	2	3	6	11	19	24	31	49	70	91	120	139	130	112	
Norway	72	79	83	89	98	103	104	107	109	111	115	116	116	112	112	110	109	108
Pakistan	0	1	1	2	3	8	22	39	54	56	58	63	68	70	73	66	71	73
Russian Federation	2	5	12	25	51	84	105	120	139	161	166	142	145	152	154	158	159	158
Rwanda	0	1	1	2	2	2	3	7	14	24	35	42	53	60	68	75	75	72
United Kingdom	74	78	83	91	100	109	115	120	121	122	121	121	122	122	121	121	120	120
United States	39	45	49	55	63	69	77	83	86	90	92	96	97	98	112	119	123	122
Uruguay	12	16	15	15	18	35	70	90	105	122	131	141	147	155	161	151	149	147
Venezuela	22	26	26	27	32	47	69	86	97	98	96	98	102	102	99	93	87	77
Viet Nam	1	2	2	3	6	11	22	52	86	112	126	142	146	135	147	129	128	126

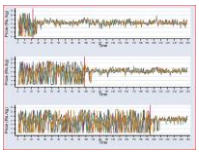
Mobile Subscriptions per 100 inhabitants

Cell phone subscriptions, 1985-2017



Fish prices in Kerala

- Study by Robert Jensen of the wholesale price of fish at beach markets in Kerala, India
- Studied prices as cell towers were build moving up the coast



Basic Mobile Phones (October, 2018)

Nokia 105
Quad band, GSM,
Dual Sim
999 rs

Fero F1100
1.2 MP Camera
900/1800Mhz
GPRS
BlueTooth
1050 Ksh

Viva V1
Single Sim, 2G
Flashlight, Snake
432 rs

Tecno T350
GSM 900 Mhz
Camera, Radio,
Facebook, Palmchat
5100 Ngn

Handset Constraints

- Connectivity
- Simcard Ownership
- Simcard Registration
- Airtime Balance
- Electrical charging
- Handset Cost

Basic Mobile Phones (GSM Standard)

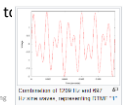
- Voice
- DTMF
  - Dual Tone Multi-Frequency
- SMS
  - Short Message Service
- USSD
  - Unstructured Supplementary Service Data

Voice + DTMF

- Analog signal for sound waves
- Converted by handset to digital data for transmission
- Multiple codecs can be used for conversion
- Voice Fundamental Frequency:
  - Male (85 to 180 Hz), Female (165 to 255 Hz)
- Speaking frequency 20Hz to 20000 Hz
- Audible through 20000 Hz
- Telephony: Frequency band 300Hz t

DTMF keypad frequencies (with sound clips)

	1209 Hz	1336 Hz	1477 Hz	1633 Hz
697 Hz	1	2	3	A
770 Hz	4	5	6	B
852 Hz	7	8	9	C
941 Hz	*	0	#	D



SMS (Short Messaging Service)

- Defined in 1985 as part of the GSM Standard
- Protocol allows seeing of up to 160 character alpha-numeric messages
- The hard thing in designing SMS was getting an agreed upon standard
  - Deutsche Telekom + France Telecom
- The first SMS was sent over Vodafone GSM Network on December 3, 1992 in the UK
- Initial growth was very slow, significant growth around 2000
  - Designed for Engineers
  - Took off when European Teenagers started using it
- SMS Gateway services are very important for building SMS applications – more later
- Hack: You can send SMS from email – 2065551212@tmomail.net

Trivia

- What was the content of the first voice call? (Alexander Graham Bell to Thomas Watson, March 10, 1876)
- What was the content of the first text message? (Neil Papworth to Richard Jarvis, December 3, 1992)
- Why are SMS messages limited to 160 Characters.

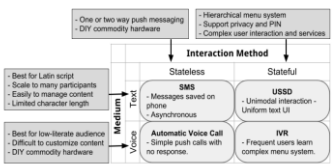
SMS Challenges

- Character limitation
- Expense
- Character Set – restricted to basic Latin characters (7-bit characters)
  - Unicode extensions require 16 bit – greatly reducing message length
- Difficulty of entering letters on a keypad
- Reliability

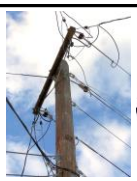
USSD Unstructured Supplementary Service Data

- Session based protocol for communicating by text between handset and service provider
- Initiated with a short code, e.g., *144# to check Safaricom balance
- 160 character strings sent back and forth between handset and provider until session is terminated
- Key differences from SMS
  - Synchronized communication
  - Direct with service provider: better security
  - Does not leave messages on the phone
- Applications
  - Adding services to cell service
  - Mobile Money
  - Yellow Pages Directory

Universal Apps (Trevor Perrier)



Phone Service



- Copper wire to house
- Phone connected to wire
- Physical exchange to connect calls
- Monopoly
- Development of standards to allow international calls
  - Technical
  - Billing

Cellular Service

- Cell Tower
  - Radio transceiver
  - Power source
  - Range: Up to 40 miles, limited by
    - Terrain
    - Technology
    - Capacity
- Aside
  - OpenBTS

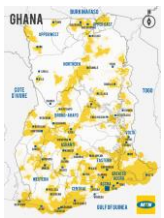
Cellular Technology

- Backhaul
  - Connecting base station to main network
  - Wired backhaul
    - Optical Fibre or Copper
  - Wireless
    - Microwave radio relay
    - High capacity radio

Cellular Connections

- Cell towers must connect to all phones in radius
  - Protocol for identifying phones
  - Needs to know to initiate action to a phone or from a phone
- Cell tower handoff
  - Mobile communication
- Connectivity info
  - Cell tower logs
  - TAC – type allocation code
  - Records all (turned on) phones
    - Not just making calls or on the network
- Call Data Records
  - Data for individual calls
    - Phone numbers, time, duration, cell tower ids

Global Cellular Coverage



Global Cellular Coverage

- Finding good cellular coverage maps is a challenge
- Areas with high population will be covered
- Low coverage in remote/mountainous areas
- Coverage between carriers is highly variable
- Often there are carriers focusing urban areas, and carriers with a rural focus
- Crowd sourced cellular data not that useful – need telco data

Telcos

- Big, global companies
- Most countries seem to have about three to five competing mobile operators
  - Possibly with some government ownership
  - A few countries have government monopolies
- List of top 15 mobile telecommunications company
  - Companies either focus on one large market or serve many countries
  - USA barely appears on this list
    - T-Mobile (Deutsche Telekom)
    - TracFone (America Movil)
  - US Based Telcos do not have a global presence
- Largest companies (by subscriptions)
  - China Mobile
  - Vodaphone Idea (India)
  - Airtel (India) [20 countries]
  - Vodaphone (UK) [26 countries]
  - China Unacom
  - China Telecom
  - America Movil (Mex) [22 countries] Claro
  - Telefonica (Sp) [20 countries] Movistar
  - Veon (Neth)[14 countries]
  - Reliance Jio (India)
  - MTN (SA) [20 countries]
  - Orange (France) [25 countries]
  - Telkomsel (Indonesia)
  - Telenor (Norway) [12 countries]
  - Deutsche Telekom (Ger) [16 countries] T-Mobile

Charging for Calls and SMS

- Telcos want to maximize ARPU
- Charging for service
  - Call cost
  - SMS cost
- Wide range of costs in different markets
  - Costs may be very high relative to income
- Charging for calls across networks
  - In-network vs. out of network
  - Charge incoming and out going
- Bundling of handset and services

Paying for calls and SMS
Prepaid vs Postpaid

- Utilities are often of poor quality in developing countries
- Cell phones are different with pre-paid models
  - Buy credit from vender
  - Buy scratch card from vendor
- Behavior when calls are very expensive (relative to income)