Democratizing Cellular Access with CellBricks

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(1: UC Berkeley, 2: Virginia Tech, 3: Facebook, 4: ICSI)
Growing the tent in cellular

- Today’s cellular ecosystem is dominated by a handful of MNOs
- Our goal: lower the barrier to entry for new entrants
  - Key: ensure small MNOs can compete equally
- This is difficult with today’s architecture!
Today’s cellular architecture

Service disruptions!
Neither of them supports small-scale access providers!

Broad coverage: *pre-established trust*
Seamless mobility: *In-network coordination*
High transaction costs of manually established agreements!
Broad coverage

MVNO

MNO 1
- mgmt
- control
- data
- mobility

MNO 2
- mgmt
- control
- data
- mobility

MNO 3
- mgmt
- control
- data
- mobility

MNO 4
- mgmt
- control
- data
- mobility

UE
Seamless mobility

Today’s architecture can provide small operators with neither broad coverage nor seamless mobility!

Frequently crossing provider boundaries disrupts services!
Start from MVNO: decoupling service providers from access providers
CellBricks

Broad coverage: move user management out of the network
Seamless mobility: move support for mobility out of the network
CellBricks

• **Goal:** Enable on-demand cellular access from any available access providers
  - No pre-established trust
  - No in-network coordination

• **Potential benefits**
  - Lower barrier to entry
  - More efficient use of infrastructure
  - High availability
  - Simpler cellular core

Is CellBricks technically feasible?
CellBricks

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**Potential benefits**

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- High availability
- Simpler cellular core

Yes, technically feasible with minimal overhead!
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- **No pre-established trust:**
  - Secure attachment
  - Verifiable accounting

- **No in-network coordination:**
  - Host-driven mobility

- **Prototype performance:**
  - Measure attachment latency
  - **Emulation over Internet:**
    - Measure app. performance
More in the paper …

• Detailed design and evaluation

• Related works

• Adoption-related problems
  • Spectrum? Incentives? Broker being new monopoly?

• Out-of-scope open questions
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• Detailed design and evaluation

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• Adoption-related problems
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• Out-of-scope open questions
Obtaining Spectrum

- CellBricks requires no changes to the RAN
  - Not dependent on spectrum policy changes
  - Can use any spectrum available to them
- Trends in spectrum regulatory environment are favorable
  - Citizens Broadband Radio Service (CBRS)
    - Dynamic spectrum sharing schemes
    - Operate without exclusive spectrum licenses
  - Regulatory constructs that allow operations in licensed but unused cellular spectrum
- License spectrum from existing MNOs (e.g. a franchise model)
Incentives for stakeholders

• New bTelcos:
  • An opportunity to join a growing and profitable market
  • CellBricks makes this opportunity more accessible to new entrants

• Brokers:
  • Business opportunity of participating in cellular market

• Users:
  • Improved coverage, more competitive cellular market

• Incumbent operators
  • Benefit from ownership of spectrum without massive financial investment
  • Incrementally deployable with no change, or cooperation from legacy operators
Won’t brokers be the new monopoly?

- Barrier to entry for starting a broker is low
  - No investments in cellular infrastructure
  - No long-term agreements with bTelcos
  - Requirement: ability to attract users and provide customer support
- It’s easy for users to switch brokers or even sign up with multiple brokers
Beyond CellBricks

- Location privacy [LOCA, NSDI’23]
  - Preserve user’s privacy without compromising network’s capabilities

- Infrastructure efficiency
  - Enable fine-grained multiplexing of cellular infrastructure

- Universal authentication
  - Allow users to efficiently leverage all the available accesses
CellBricks

• A radically different cellular architecture:
  • Lower barrier to entry for new operators
  • Enable a simpler and more efficient cellular infrastructure

• How?
  • Move user management into broker and UE
  • Move mobility support into end hosts

Technically feasible with minimal performance overhead!
Thanks!

- **Webpage**: [https://cellbricks.github.io](https://cellbricks.github.io)

- **Implementation**: [https://github.com/cellbricks](https://github.com/cellbricks)

- **Artifacts**: [https://cellbricks.github.io/artifact-sigcomm21/](https://cellbricks.github.io/artifact-sigcomm21/)

- **Contact**: zhluo@berkeley.edu
Backup slides
Secure Attachment

Session SID1: <User Bob, bTelco 2>

QoS info, security context

"User=Bob; Broker=Google; bTelco=bTelco2"
Traffic reports contain:
1) Session identifier
2) Relative timestamp
3) Usage metrics
4) QoS metrics

User’s device hardware generates traffic reports (trusted and tamper-proof)
Host-driven Mobility

• Today, handovers require coordination between towers
  • Allows a UE’s IP address to stay unchanged

• In CellBricks, handovers may involve different bTelcos
  • Difficult to preserve a UE’s IP address across admin boundaries

• Solution: leverage modern transport protocols (MPTCP, QUIC)
  • L4 connection is maintained even if the UE’s IP address changes

Moving mobility support out of the network and into the transport
MPTCP as an example

- Subflow: TCP segments that operate over an individual path
- How does a single-subflow connection react to IP changes?
  - At the end of detachment:
    - Previous IP address is invalidated by the baseband
    - MPTCP stack is notified of the invalidation
    - Watch for new address until reaching a predefined timeout
  - After the new attachment:
    - New IP address assigned
    - MPTCP uses new source IP to initiate a three-way handshake to create a new subflow, also informs the server to remove the previous subflow
    - Once the new subflow is established, the connection resumes
CellBricks: putting the pieces together
Prototype

- USRPs
  - Provide radio connectivity
- srsLTE
  - UE and eNodeB
- Magma
  - AGW: extended to support secure attachment
  - Orc8r: added a Brokerd service
Measure end-to-end latency of our attachment protocol

UE, eNodeB, AGW in local machines

Vary locations for SubscriberDB (S6a) and brokerd
Emulation over Internet

- Emulation over existing cellular and wide-area networks
  - Performance of real applications under real-world conditions
- Applications
  - iPerf, video streaming, web page loading, VoIP
- Methodology
  - Detect handovers
  - Emulate IP changes (with injected latencies)
  - MPTCP reacts to IP changes
### Overall Application Performance

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**Negligible performance impacts: between -1.6% to 3.1% of the baseline**