Background and motivation

**Massive capital investments in wireless**
- 2000-2004: About $100B annually in the US
- Total of over $100B on European spectrum alone
- Significant entry barriers (spectrum, fixed costs)

**Flat/declining revenues and quality**
- US ARPU flat as service features, traffic increased
- Declining revenue per MOU across all carriers
- Declining measured service quality

**Questionable viability of 3G, UMTS upgrades**

Research agenda

**Model competition in wireless telecom**
- Capture interdependence between traffic, spectrum, transmission technology, infrastructure and service quality
- Incorporate congestion, minimum infrastructure needs
- Relate profits, revenue, return on assets and market share to changes in demand and transmission technology

**Based on this model**
- Explain some revenue and CAPEX trends
- Prescribe pricing, quality and migration strategies
- Examine industry concentration and policy issues

Summary of some key results

**Externalities and pricing power**
- Increases the slope of profit functions, equilibrium prices
- Mediates the need for quality differentiation
- However, their extent depends critically on average traffic

**Revenue and investment trends**
- ARPU is flat over a range of traffic levels, then declines
- Profits are occasionally lower for the higher quality firm, ROI is often lower

**Strategy for providers**
- Low infrastructure, similar quality (early-stage)
- Aggressive quality differentiation (mature market)
- Migration to a new transmission technology

Related literature (briefly)

**Wireless telecom and service quality**
- Valetti (1999)
- Sweet, Viehoff, Linardatos and Kaloutsids (2001)

**Congestion pricing**

Overview of model

**Competition between two wireless providers**

**Service quality determined by**
- Effective channels per cell $v_i$, (spectrum, transmission technology)
- Number of base stations $N_i$ per unit area (cell size), with a minimum deployment constraint $N_{min}$
- Market share (negative externality demand imposes on quality)

**Customer characteristics**
- Homogeneous demand for $E$ erlangs of traffic per unit time
- Heterogeneous valuation of service quality
Overview of model

- Average traffic per user: $E$
- Market share of firm $i$: $x_i$
- Service quality of firm $i$: $[1 - B(v_i, \rho_i)]$
- Value to customer: $w(E)[w + B_i] - p$

Equilibrium infrastructure deployment

Three kinds of first-stage equilibria
(a) Symmetric minimum deployment
(b) Asymmetric with one firm deploying minimum
(c) Asymmetric with neither firm deploying minimum

Equilibrium prices

Timeline

- Market share for Firm B
- Market share for Firm A

$$p^A(N_A, N_B) = u(E)(1 - y)p(y)$$

$$p^B(N_A, N_B) = u(E)y(p(y))$$

Evolution of infrastructure deployment

- Transitions take place at average traffic thresholds $E$, $E'$, $E''$
- Asymmetric to minimum
- Minimum infrastructure investment at both very low and very high levels of average demand per user

Results: variation in pricing (ARPU)

- Sharp initial rise in prices with traffic increases
- Infrastructure keeps pace with traffic growth, prices flat
- Incremental deployment drops, externalities force quality down
Variation in profits

- Pricing power and low infrastructure drives up profits initially
- Flat prices, increasing infrastructure reduce profits, decline accelerates as prices fall
- Zero-profit threshold suggests necessary migration point

Technology migration cycles

- Technology migration increases number of effective channels
- Pricing and profit trends are similar, but 'expanded'
- Suggests cycle of migration → pricing power → flat ARPU → next migration

Implications for provider strategy

Early-stage wireless markets
- Choose similar quality, low infrastructure
- Leverage pricing power from externalities

Mature wireless markets
- Pursue aggressive quality differentiation
- Expect flat/declining revenue per user

Late-stage wireless markets
- Slow/cut back on infrastructure deployment
- Actively plan and implement next migration

Market power and relative concentration
- Welfare implications of recent mergers
- Herfindahl-Hirschman index may understate market power

Oligopoly and spectrum policy
- Multiple providers and equilibrium market structure
- Calibrated guide to profitability of additional spectrum

Technology migration games
- Stage-payoffs in multi-period adoption game
- Optimal timing of migration

Ongoing work