Optimized Policies for Adaptive Control (OPAC)

Session 1: Principles of Operation

Nathan H. Gartner
University of Massachusetts, Lowell

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OVERVIEW

- Adaptive vs. Fixed-Time
- OPAC Model Development
- System Architecture
- Traffic Flow Profiles
- Timing Optimization
- Virtual Fixed-Cycle Concept
- Over-saturated Conditions
- Pre-emption
Fixed-time Systems

- UTCS-1GC / Closed-Loop Systems:
  - Pre-stored timing plans in a library
  - Developed off line, using historical data
  - Control plans are not responsive to dynamic and volatile traffic demands
  - Ageing – timing plans become outdated resulting in deteriorating performance over time
Adaptive Traffic Control: OPAC and Other Systems

• Real-time signal timing based on measured and predicted traffic demands
• Seeks continuous optimal system performance in response to both short term and long term variations in traffic
• Can be combined with DTA to optimize signal control and traffic routing (assignment)
Adaptive Control Systems

- Require extensive deployment of traffic detectors and surveillance equipment
- Eliminate the need for signal re-timing
- Reduce maintenance and operations costs
What Is OPAC?

- OPAC is a distributed real-time traffic signal control system
- Continuously adapts signal timings to minimize a performance function of total intersection delay + stops over a pre-specified horizon
- Can operate as an independent smart controller, or as part of a coordinated system
Principles for Development of OPAC

• Must provide better performance than off-line methods

• Requires development of new concepts

• System must be truly demand-responsive, i.e. adapt to actual traffic conditions

• Must not be restricted to arbitrary control periods, but capable of frequent or continuous updating of plans
OPAC MODEL DEVELOPMENT
(Optimized Policies for Adaptive Control)

- OPAC I: dynamic programming optimization, infinite horizon (single intersection)
- OPAC II: OSCO search procedure, finite projection horizon length
- OPAC III: first use of ‘rolling horizon’ approach
- OPAC-RT: real-time implementation
OPAC MODEL DEVELOPMENT
(continued)

• OPAC IV = VFC-OPAC: network model for real-time traffic adaptive control (VFC Principle)

• OPAC V: pro-active control, integration with DTA for combined control-assignment
OPAC MODEL DEVELOPMENT
(timeline)

- OPAC I – 1979
- OPAC II – 1980
- OPAC III – 1981
- OPAC-RT – 1986
- OPAC IV – 1995
- OPAC V – 2000+
Characteristics of OPAC IV

• Real-time, traffic adaptive control of signals in a network
• Distributed optimization based on individual OPAC smart controller
• Multi-layer network control architecture
• VFC Principle: Variable cycle in time and in space within bounds
Control Layers in OPAC IV

• **Layer 1**: optimal switching sequences for projection horizon, subject to VFC constraint

• **Layer 2**: real-time optimization of offsets at each intersection

• **Layer 3**: signal synchronization: network-wide calculation of VFC
Rolling Horizon Approach

Projection Horizon

Roll Period

0  k  n

Projection Horizon

Roll Period

k  2k  k+n
Developing Flow Profiles

- A flow profile is developed for each phase using a user-specified horizon length.
- Head of profile is actual counts from upstream link detectors.
- Tail of profile is projected for near future using smoothed volume counts.
- Platoon identification is used for cyclic profiles.
Phase Length Optimization

- Flow profiles on all approaches to the intersection are processed through sequence of settings for the horizon duration
- Performance function is evaluated for each control setting
- Decision is made whether to terminate current phase or extend it by one interval
- Interval length = 1 or 2 sec
Offset Optimization

• Decision on new offset is made at the end of the current cycle
• Performance function is evaluated for three alternatives: +?, -?, 0
• MOEs of the three alternatives are compared and the best performance offset is selected
The Virtual Fixed Cycle (VFC) Concept

- Allows the cycle time to start or terminate within a flexible range at each intersection
- Provides maximum leeway for individual controller as determined by local demands
- ... while maintaining capability for coordination with adjacent intersections for improved progression of vehicle platoons
Virtual Fixed Cycle (VFC) Optimization

• Real time identification of “dominant” intersection in each sub-network
• Optimal VFC is calculated on-line and imposed as additional constraint on all controllers
• Cyclic flow profiles are adjusted
OPAC Conceptual Design

Traffic Network

Detector data

Platoon Prediction

Flow profiles
Average speed
Occupancy

Phase Flow Characterization

Field Signal State

- Elapsed time since last signal status changed
- Signal status

Intersection Optimization Logic

Network Synchronization

- Virtual cycle
- Cycle Constraints

Peer-to-peer information

Offset

Flow profiles

Downstream Intersection Simulation

Parameter and state estimation:
- Queue length
- Stops
- Delay

Initial parameters

Principal Intersection Simulation

Intersection geometry
Discharge characteristics
Phasing Flexibility

- Optimization of up to eight phases in a dual ring configuration
- Supporting all combinations of left turn lead/lag phasing
- Phase skipping in the absence of demand
- Phasing sequence based on time of day
Oversaturated Conditions

- Isolated intersection mode:
  - Provides maximum green to the affected phase(s) if occupancy exceeds a user-specified threshold

- Coordinated mode:
  - Provides maximum green to congested phases, subject to the current cycle length
  - Adjusts cycle length in response to increasing congestion
Preemption

- Preemption will always take priority over OPAC
- Prioritizes transit and emergency vehicles if they are restricted to particular lanes
- Recovers from a preemption immediately
OPAC Implementations

- Single intersections:
  Arlington, Virginia
  Tucson, Arizona

- Arterials + Networks:
  New Jersey - Route 18
  Reston Parkway