Traffic Classification and Observer Design of Cable Networks

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Motivations

- The solution to the previously-discussed problems in cable networks is a feedback control mechanism
- A feedback controller operates depending on the system states of interest
- Using raw system states, such as bytes received, is very (perhaps prohibitively) expensive
- An observer is needed to estimate some abstract system states of interest

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Purposes

- This paper is the second phase of our research. It is intended to design an observer for the control system of cable networks
- The construction of the observer is recast into a traffic classification problem
- This is the first part of the solution to the problems raised previously

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Contributions

- Provides a cable network observer model
- Gives an observer design for the control system of cable networks

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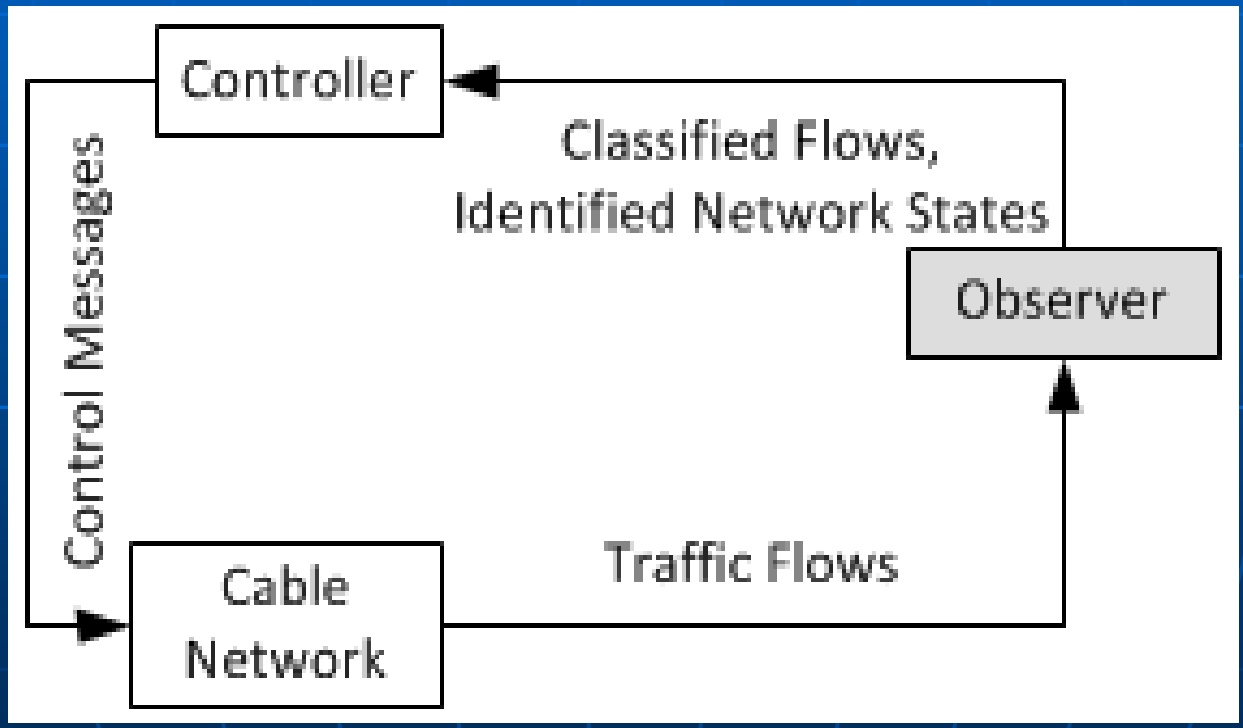
Feedback Control of a Cable Network

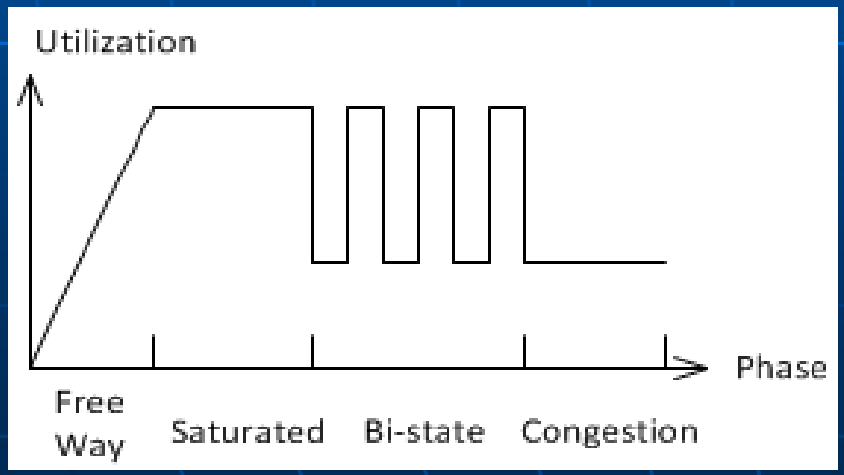


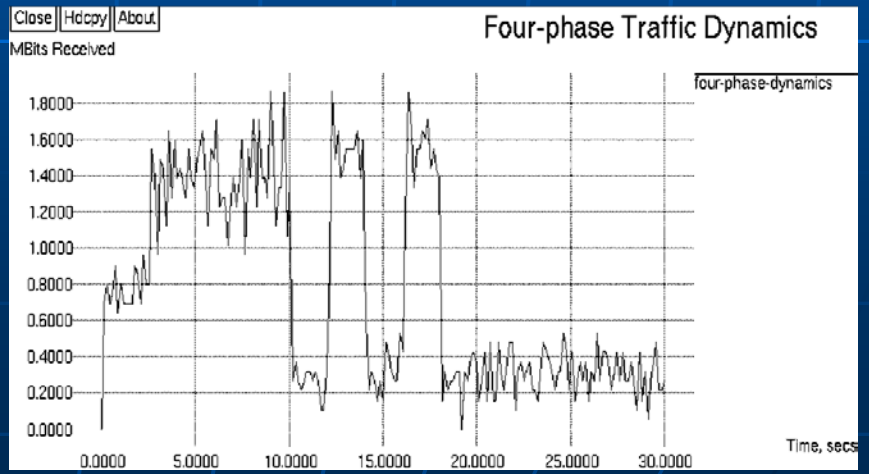
Functions of the Observer

- Estimate bandwidth allocations and network utilization
- Classify flows
- Identify network states

Four-Phase Traffic Dynamics

- The left figure shows the four-phase dynamics hypothesized
- The right figure shows the four-phase dynamics obtained by an NS2 simulation
- Combination of the four phases and fairness indicators forms the abstract state space of the cable network to be controlled





9-Tuple Cable Network Observer Model

Cobs={ T_{delta}, Alloc, FL, F, NF, FC, NS, f, g}

- T_{delta} is a set of small identical **time intervals**. $T_{delta} = \{\Delta_1, \Delta_2, \ldots, \Delta_j, \ldots\}$
- Alloc is a set of **bandwidth allocations** of the cable network. $\{s_1, s_2, \ldots, s_n\} \in$ Alloc
- FL is a set of **traffic flows** of a cable network
- $F = F_1 \times F_2 \times \ldots F_i \ldots \times F_n$. F_i is the **feature space** for flow i

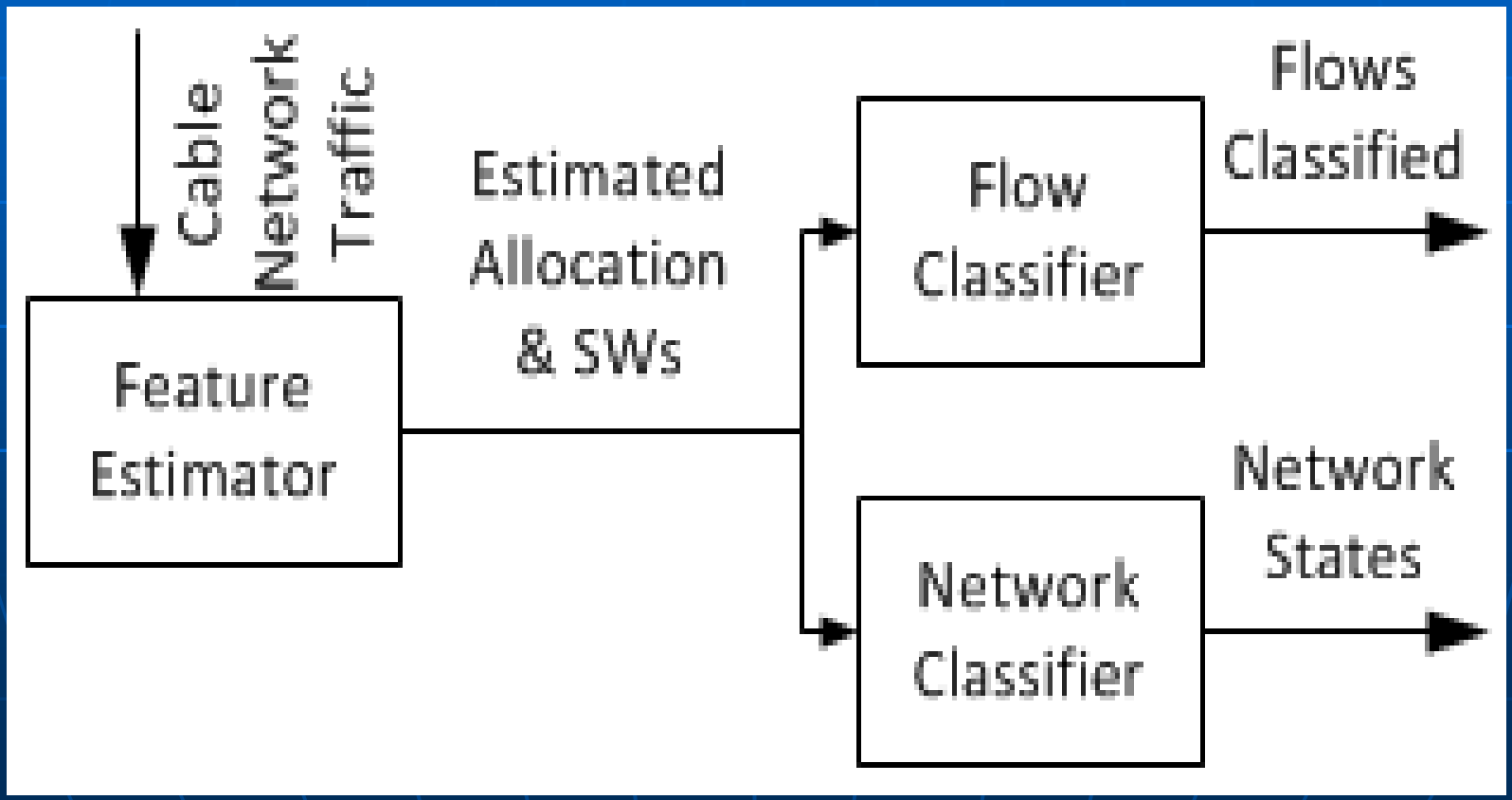
9-Tuple Cable Network Observer Model (Continued)

- NF is a set of **network features**, i.e. network feature space
- FC is a set of **flow classes**. FC = {Light, Normal, Heavy} in this paper
- NS is the **abstract state space** of the cable network. In this paper, NS = (PHASE x FAIRNESS). PHASE = {Free Way, Saturated, Bi-State, Congestion} and FAIRNESS = {Fair Traffic, Unfair Traffic}
- f is a **flow classification assignment**, i.e. a map f: FL $\rightarrow$ FC
- g is a **network state assignment**, i.e. a map g: NF $\rightarrow$ NS

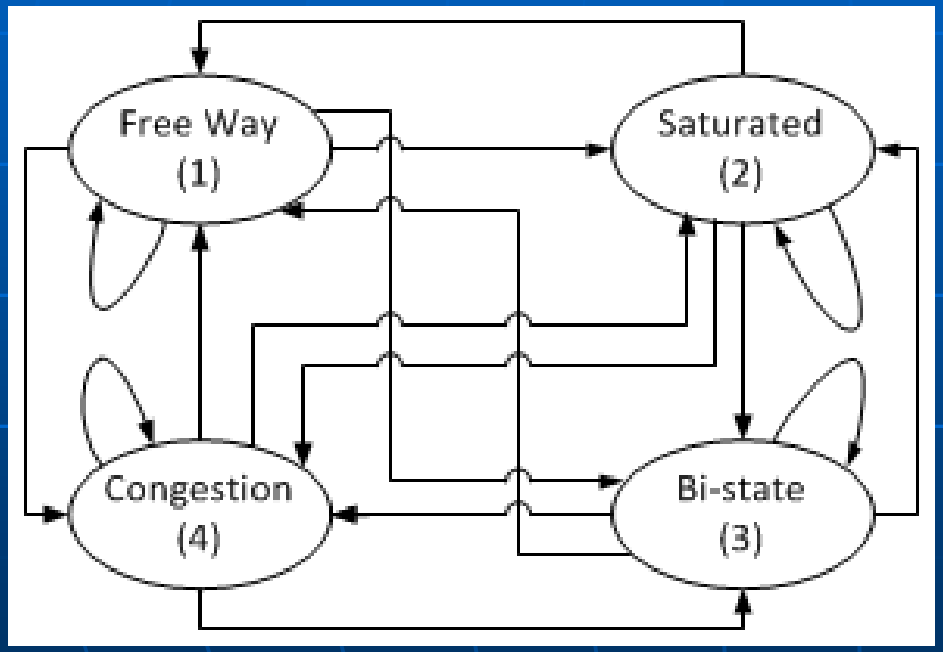
Flows & Features

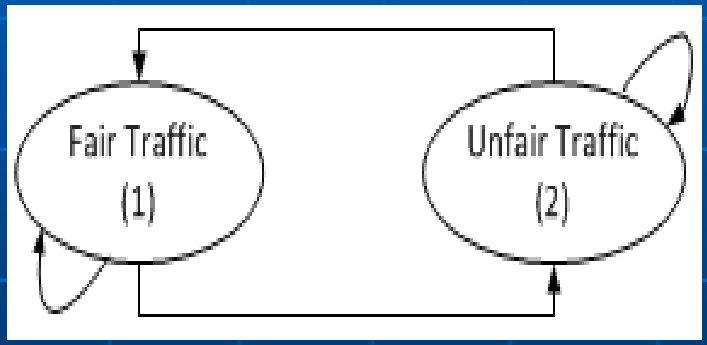
- A flow is defined as a sequence of frames originated from the same CM
- The feature space of a flow, fl_i, is defined as the state of CM_i, $s_i, \in [0, 1]$, i.e. $F_i = \{s_i\}$
- The feature space of a cable network is defined as $NF = \{sw_1, sw_2, ..., sw_L\}$

Architecture for the Classifier of Cable Networks

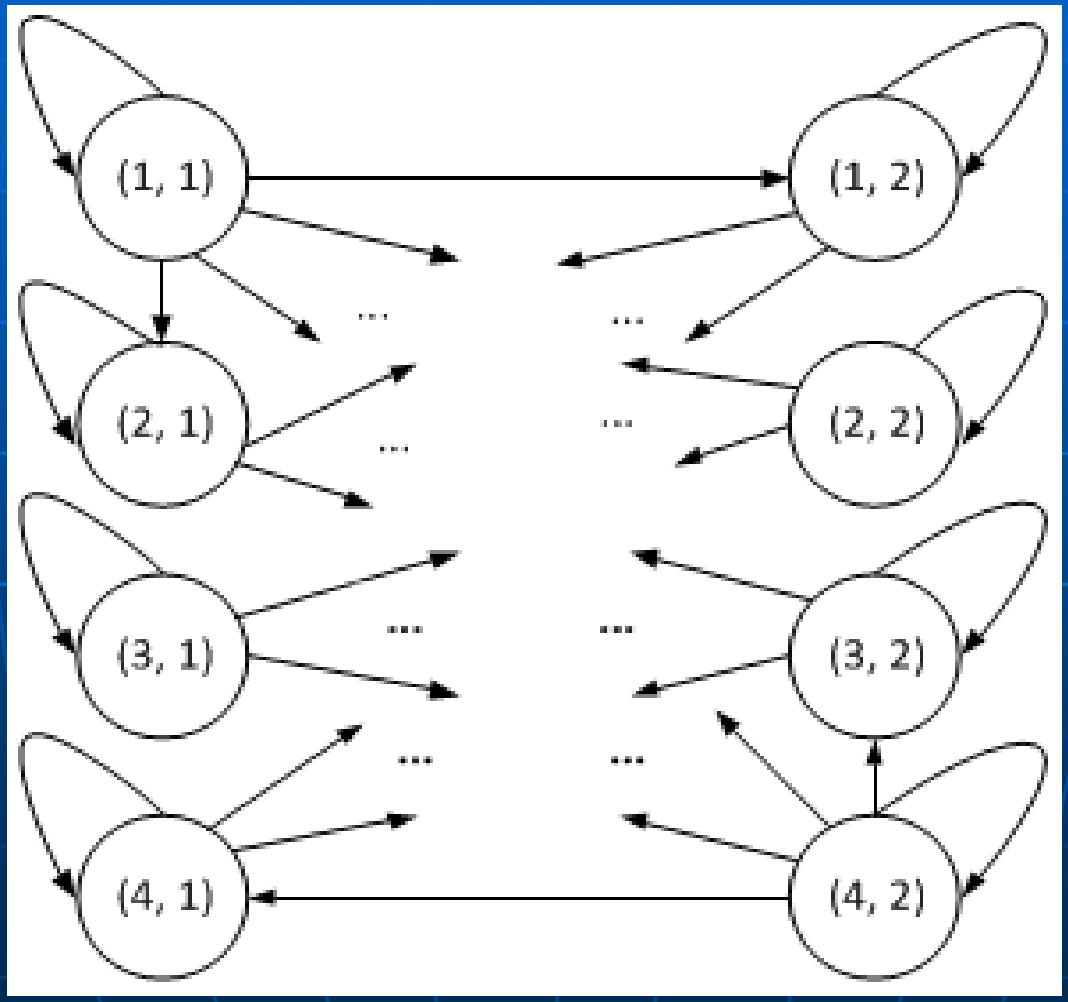


Utilization HMM & Fairness HMM





Network State Diagram, An HMM



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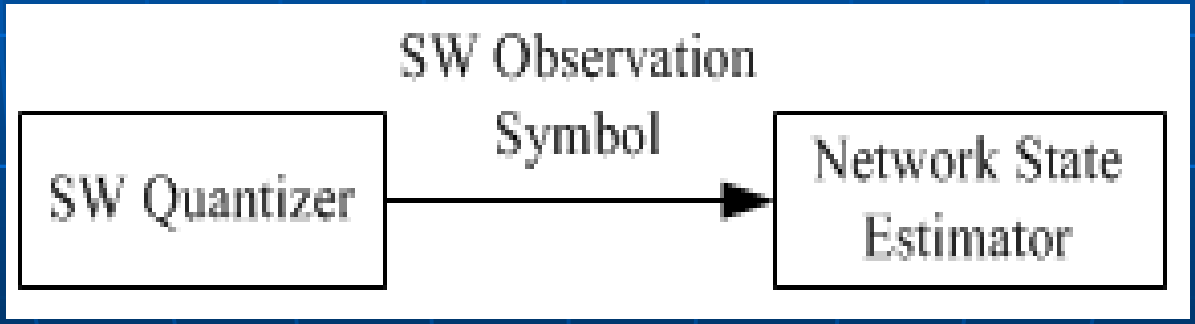
Network Classifier Components



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Next Work

- Controller design for cable networks
- Observer and controller designs together provide a solution to the problems described in the first phase