A Markov Model of Server to Client IP traffic in First Person Shooter Games

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Outline

- Modelling of traffic
- First Person Shooter games
- Assumptions used in modelling game traffic
- Comparisons of predictions with empirical results
  - Time independent behaviour
  - Time dependent behaviour
- Results from First Person Shooter traffic simulator

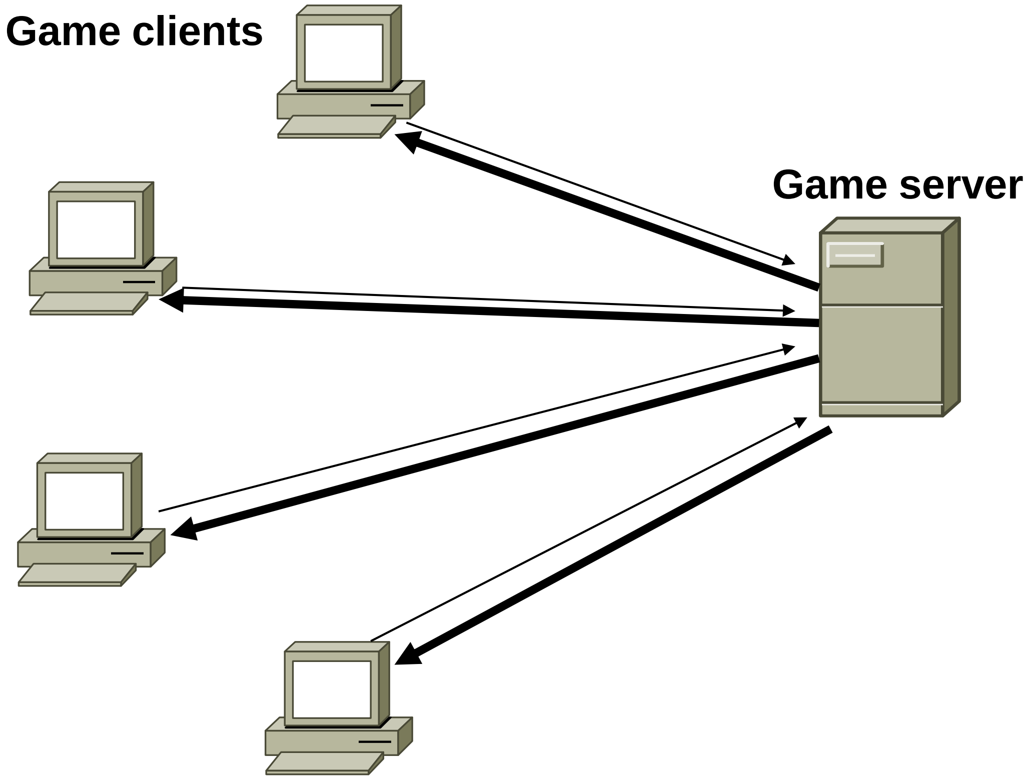
Modelling of game traffic

- Goals are
  - Understanding game traffic
  - Using our understanding to
    - Predicting what game traffic will look like for new games
    - Predict how game traffic will change as the number of players increases
- Main question is
  - If we have statistics of 2 and 3 player games, can we predict traffic statistics of 4, 5, 6, … player games?
  - Knowing the mean, variance and Probability Mass Function (histogram) of games with small numbers of players can we predict the same for games with larger numbers of players
- Can we model game traffic?

Why not just look at the source code?

- We have for some games
  - But usually source code is not available
- Source code (where available) supports our assumptions
  - Game traffic highly compressed
  - Game engine acts as a linear system that maps player input to output
- In other words, game traffic behaviour is driven by random player behaviour suitable for modelling with Stochastic methods

First Person Shooter Games



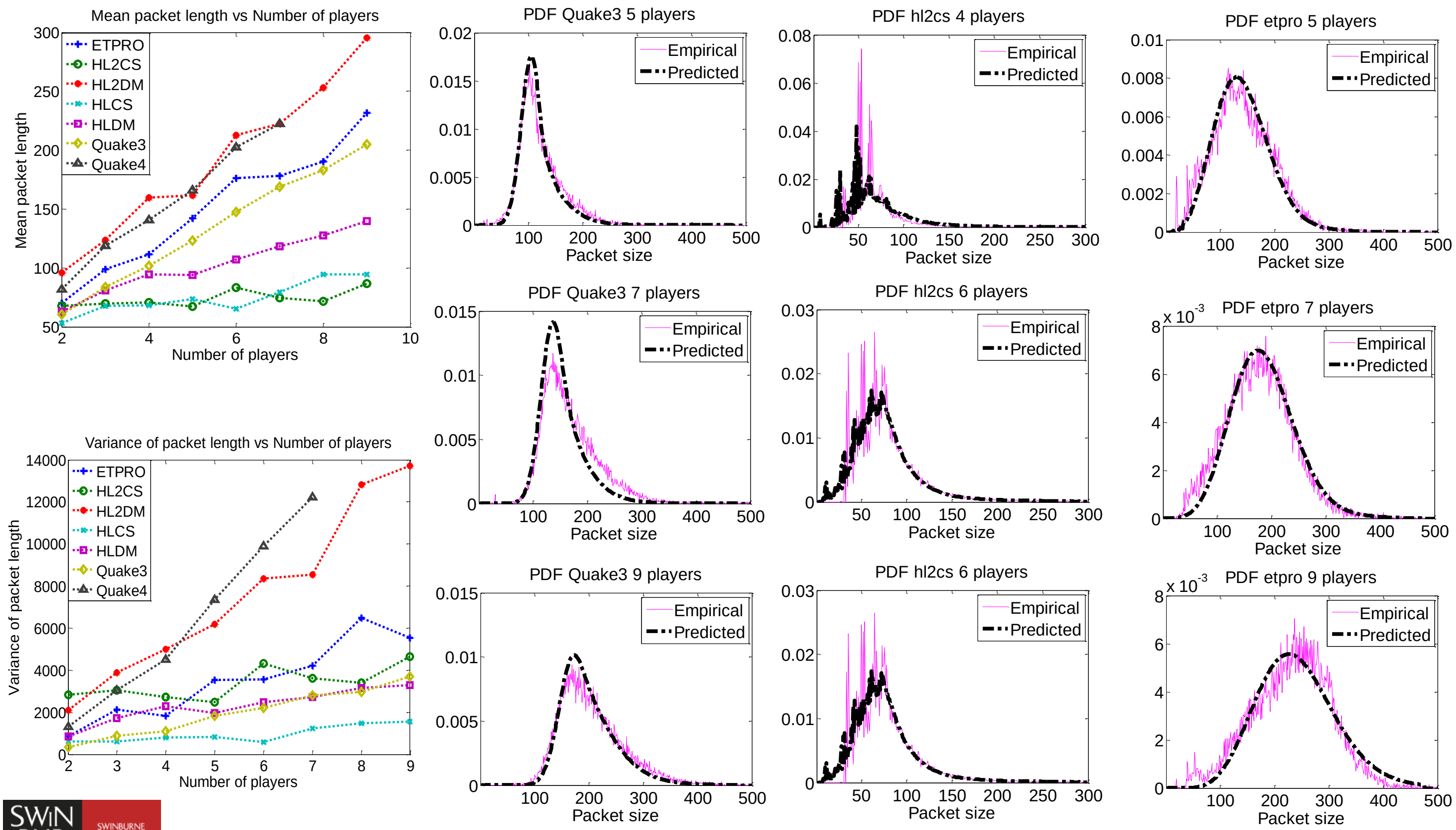
First Person Shooter Games

- FPS Games client-server architecture
- Traffic from the clients transmitted to the server
- Server processes inputs from clients and determines consequences
  - Eg explosions, game points, character deaths etc
- Random variables of interest include
  - Client to server packet rates
  - Client to server packet lengths
  - Server to client packet rates
  - **Server to client packet lengths**
- Server to client packet lengths of most interest
- Detailed analysis of game traffic from seven different games
  - Q3, Q4, ETPro, HLDM, HLCS, HL2DM and HL2CS

Model of game traffic

- Assumptions
  - The nature of game play for individual players does not change significantly regardless of the number of players.
  - Players have similar behaviour.
  - Game software compresses its output.
- From the assumptions we can make a number of predictions
  - N-player game statistics should be predictable from 2 and 3 player game statistics, for example
    - The probability distribution of packet lengths of a 5-player can be predicted from the prob. dist of a 2- and 3-player games
    - X5 = X2 + X3
  - Statistics to evaluate are the mean, variance and Probability Mass Function
  - Mean and Variance should increase linearly as number of players increase
  - PMFs should be predictable from X2 and X3
    - Eg f_{x5} should be the convolution of f_{x2} and f_{x3}

Time independent behaviour

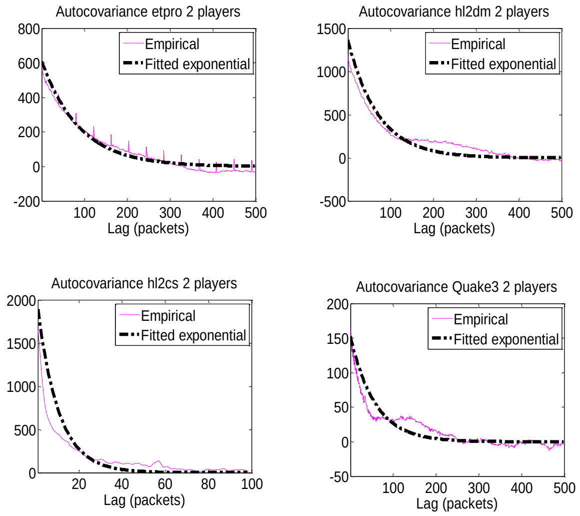


Time varying behaviour

- Autocorrelated nature of game traffic not captured by simple probability mass functions
- We would expect game traffic to exhibit some autocorrelation
  - Periods of intense actions last for seconds
    - Will generate trains of large packets
  - Quiet periods also last for seconds
    - Will generate trains of short packets
  - Would expect that the length of the current packet will be a good predictor of successive packets
    - In other words we would expect to see some autocorrelation between packet lengths

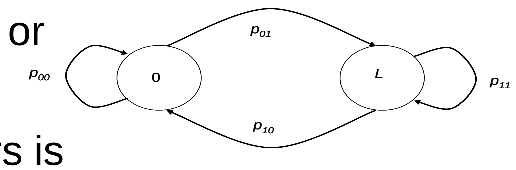
Autocorrelation functions of game traffic

- FPS Game traffic is strongly autocorrelated
- Autocorrelation function modelled reasonably well with exponential distributions
- Indicates that a Markov model of game traffic may be appropriate
- We have developed a Markov Chain model to predict game traffic behaviour



Markov Chain model

- Assume that each player contributes to server traffic through generating traffic or not generating traffic
- Assume that the behaviour of *N* players is identical, independent regardless of the number of players.
- The aggregate behavior of *N* identical, independent Markov chains can be described by a matrix A where the individual terms are given by:



$$a(n_1,n_2)=\sum_{k=0}^{n_1}\left[\binom{n_1}{k}(1-p_{11})^k\,{p_{11}}^{n_1-k}\binom{N-n_1}{n_2-n_1+k}(1-p_{00})^{n_2-n_1+k}\,{p_{00}}^{N-n_2-k}\right]$$

Markov Chain model

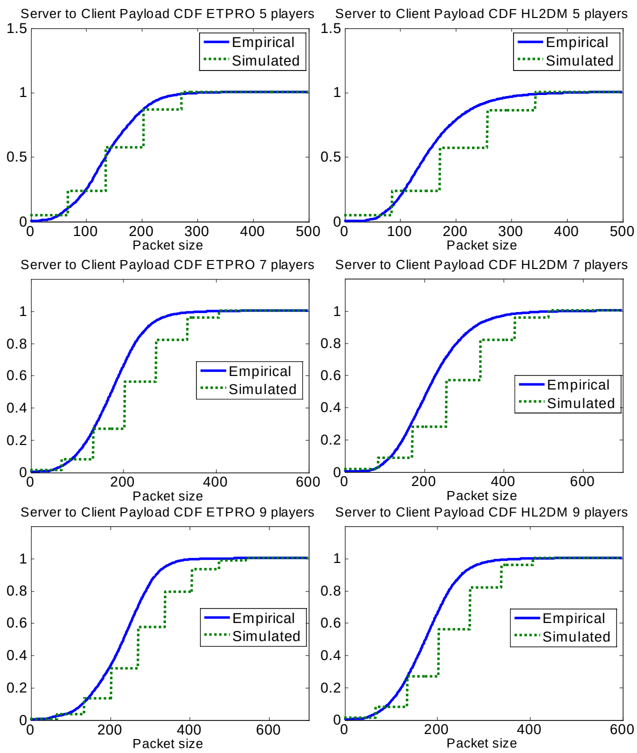
TABLE 1.

Five player Predicted and Empirical Transition Matrices

ETPRO		HL2CS	
Predicted	Empirical	Predicted	Empirical
$\begin{pmatrix} 0.71 & 0.25 & 0.04 & 0.00 & 0.00 \\ 0.06 & 0.72 & 0.20 & 0.02 & 0.00 \\ 0.00 & 0.11 & 0.72 & 0.15 & 0.01 \\ 0.00 & 0.01 & 0.17 & 0.72 & 0.10 \\ 0.00 & 0.00 & 0.03 & 0.22 & 0.70 \end{pmatrix}$	$\begin{pmatrix} 0.79 & 0.19 & 0.01 & 0.00 & 0.00 \\ 0.05 & 0.79 & 0.15 & 0.01 & 0.00 \\ 0.00 & 0.16 & 0.71 & 0.11 & 0.01 \\ 0.00 & 0.03 & 0.34 & 0.57 & 0.05 \\ 0.01 & 0.04 & 0.21 & 0.45 & 0.26 \end{pmatrix}$	$\begin{pmatrix} 0.72 & 0.24 & 0.03 & 0.00 & 0.00 \\ 0.06 & 0.73 & 0.19 & 0.02 & 0.00 \\ 0.01 & 0.12 & 0.72 & 0.14 & 0.01 \\ 0.00 & 0.02 & 0.18 & 0.71 & 0.09 \\ 0.00 & 0.00 & 0.03 & 0.24 & 0.68 \end{pmatrix}$	$\begin{pmatrix} 0.74 & 0.24 & 0.01 & 0.00 & 0.00 \\ 0.05 & 0.85 & 0.09 & 0.00 & 0.00 \\ 0.01 & 0.56 & 0.39 & 0.03 & 0.00 \\ 0.04 & 0.39 & 0.39 & 0.15 & 0.01 \\ 0.11 & 0.48 & 0.26 & 0.11 & 0.04 \end{pmatrix}$
HL2DM		**Quake 3**	
Predicted	Empirical	Predicted	Empirical
$\begin{pmatrix} 0.68 & 0.27 & 0.04 & 0.00 & 0.00 \\ 0.06 & 0.69 & 0.22 & 0.03 & 0.00 \\ 0.01 & 0.12 & 0.70 & 0.16 & 0.01 \\ 0.00 & 0.02 & 0.18 & 0.69 & 011 \\ 0.00 & 0.00 & 003 & 0.24 & 0.68 \end{pmatrix}$	$\begin{pmatrix} 0.62 & 0.34 & 0.03 & 0.01 & 0.00 \\ 0.07 & 0.75 & 0.15 & 0.02 & 0.00 \\ 0.01 & 0.32 & 0.55 & 0.10 & 0.01 \\ 0.01 & 0.16 & 0.47 & 0.31 & 0.05 \\ 0.01 & 0.14 & 0.31 & 0.32 & 0.17 \end{pmatrix}$	$\begin{pmatrix} 0.54 & 0.35 & 0.09 & 0.01 & 0.01 \\ 0.09 & 0.57 & 0.28 & 0.05 & 0.00 \\ 0.02 & 0.18 & 0.57 & 0.21 & 0.03 \\ 0.03 & 0.05 & 0.27 & 0.55 & 0.13 \\ 0.00 & 0.01 & 0.09 & 0.34 & 0.50 \end{pmatrix}$	$\begin{pmatrix} 0.54 & 0.39 & 0.04 & 0.00 & 0.00 \\ 0.01 & 0.66 & 0.27 & 0.05 & 0.00 \\ 0.03 & 0.40 & 0.47 & 0.18 & 0.03 \\ 0.00 & 0.30 & 0.47 & 0.17 & 0.02 \\ 0.00 & 0.40 & 0.48 & 0.08 & 0.04 \end{pmatrix}$

Simulation based on model

- ns2 simulations based on the model
- Provide a reasonably good approximation of real traffic
- Very simple to implement
  - Can be implemented quickly for new games
  - Only need traffic statistics for a two player game
- Main limitation is that the traffic generator produces “quantized” payload sizes



Conclusion and further research

- Some work on modelling with ARMA(1,1) models
  - Perhaps more accurate but much more complex to implement
- Other game genres
  - Do other games possess similar properties?
  - Some indications that they might
- Implementation and application of simulator models based on this work