“Quantum” Classification of Malware

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whoami

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- Actively studying/researching infosec for about three years (mostly academic)
- Currently work for CyberPoint International

Outline

- D-Wave Basics
  - The D-Wave Controversy
  - How to play around on a D-Wave
- Some Machine Learning Background
- Building a “Quantum” Malware Classifier



https://blog.kaspersky.com/quantum-computers-and-the-end-of-security/

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What you might have heard (and why it's wrong)

- FALSE: The D-Wave can solve NP-Complete problems in polynomial time.

- PROBABLY FALSE: The current D-Wave chip is already "better" than classical computing for hard problems.

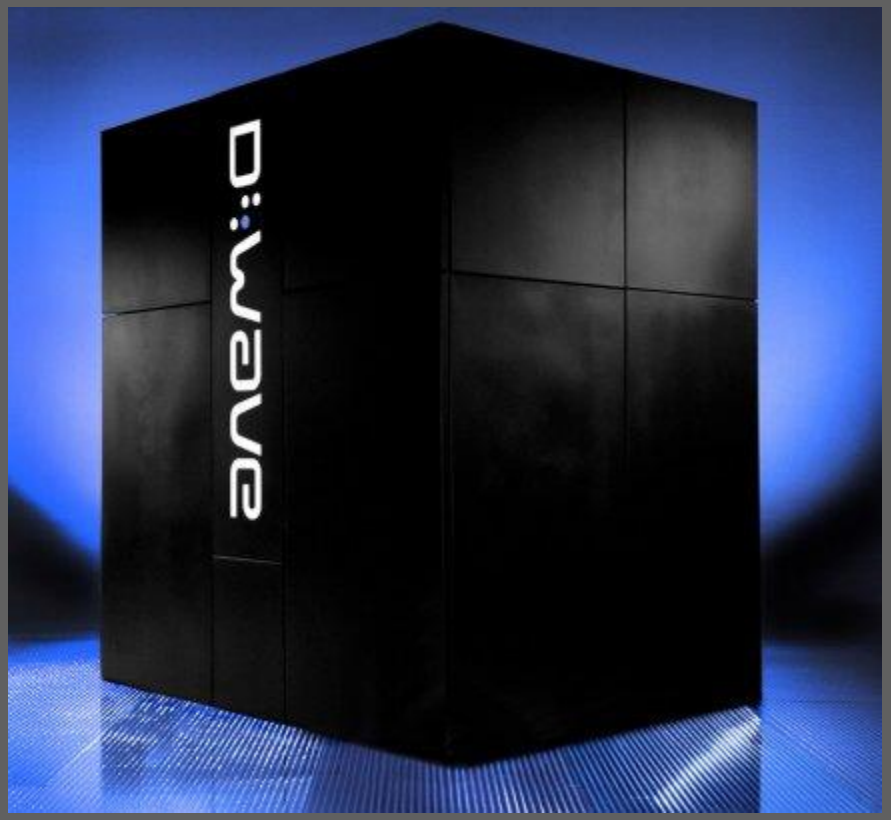
The Current State of Affairs

Quantum effects are happening…

…but that might not be interesting

We don't know whether the D-Wave uses quantum effects for computation.

Regardless, it cannot run Shor's/Grovers/QKD.



http://www.dwavesys.com/

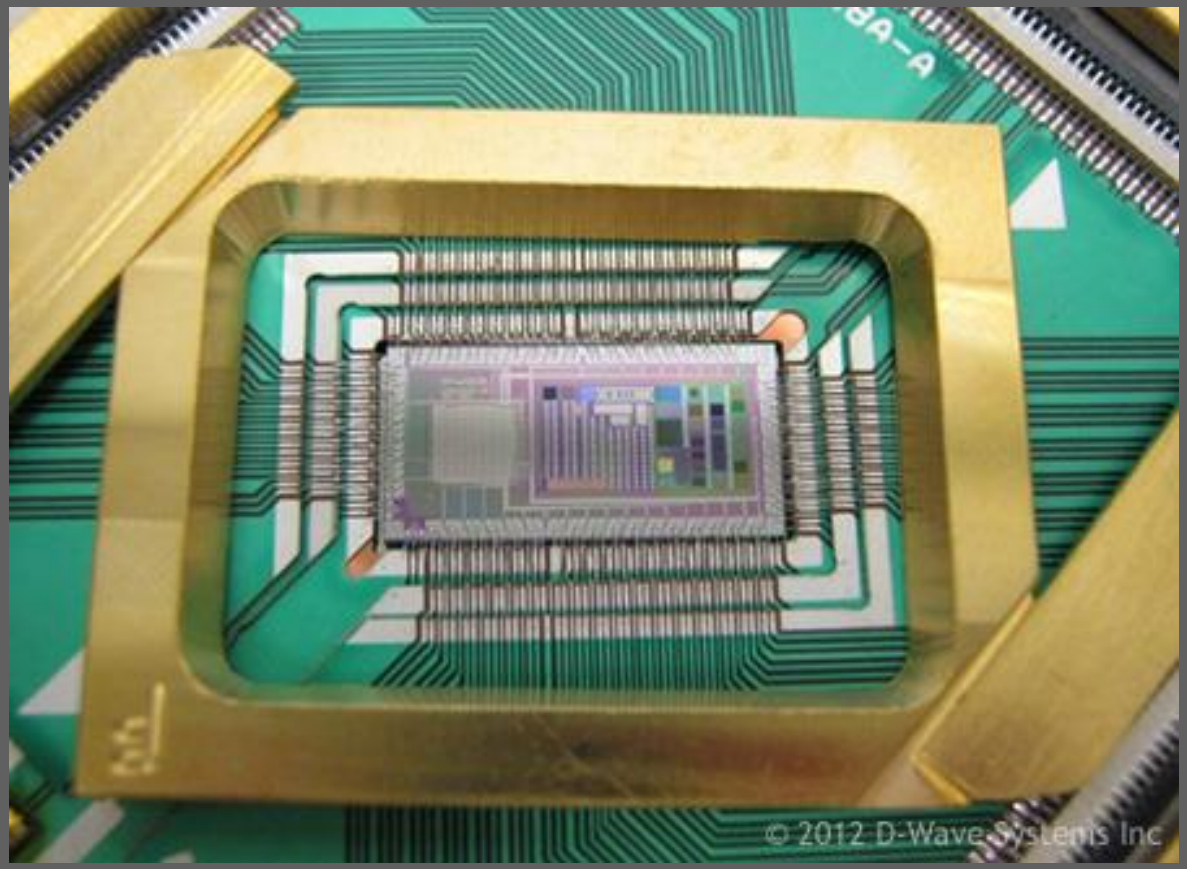


http://www.nytimes.com/





http://www.nytimes.com/



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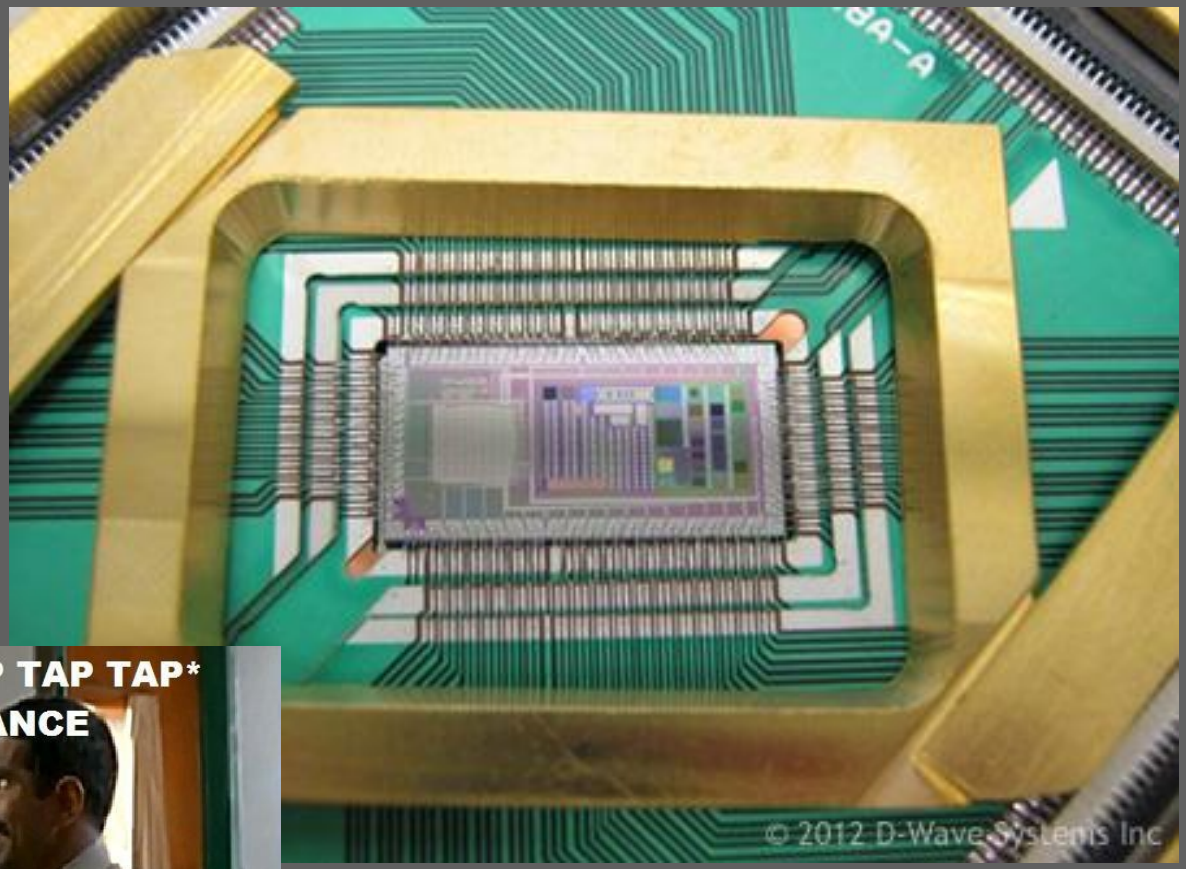



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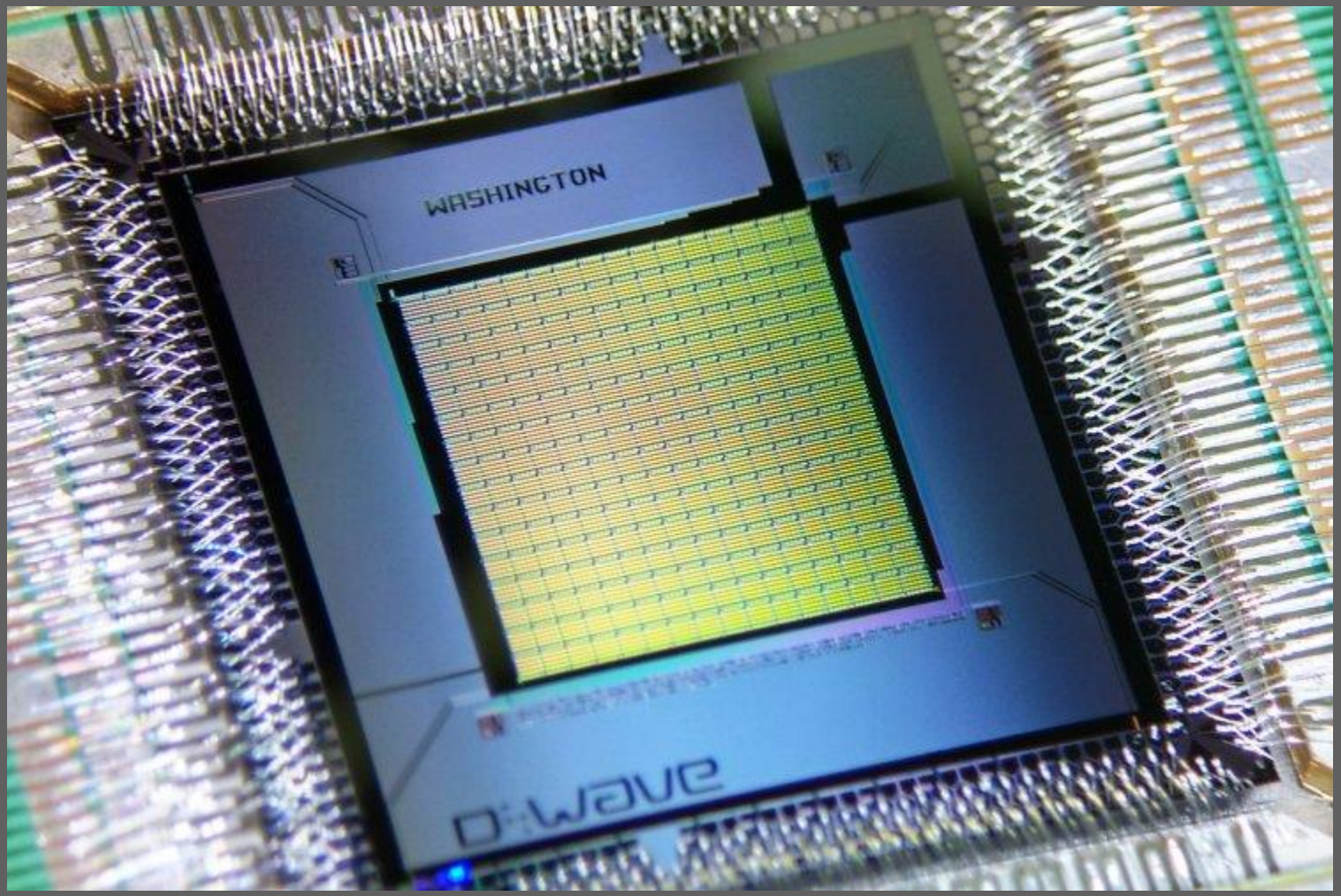
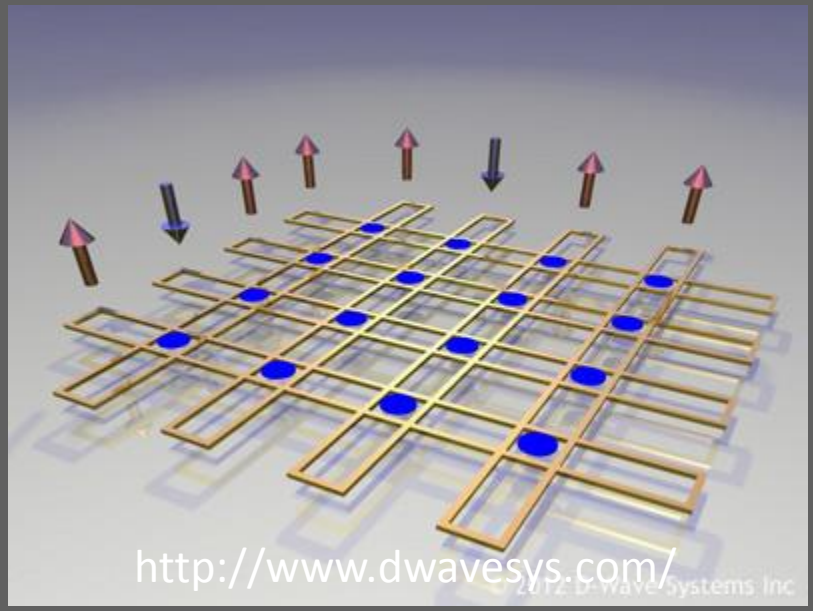


http://www.dwavesys.com/

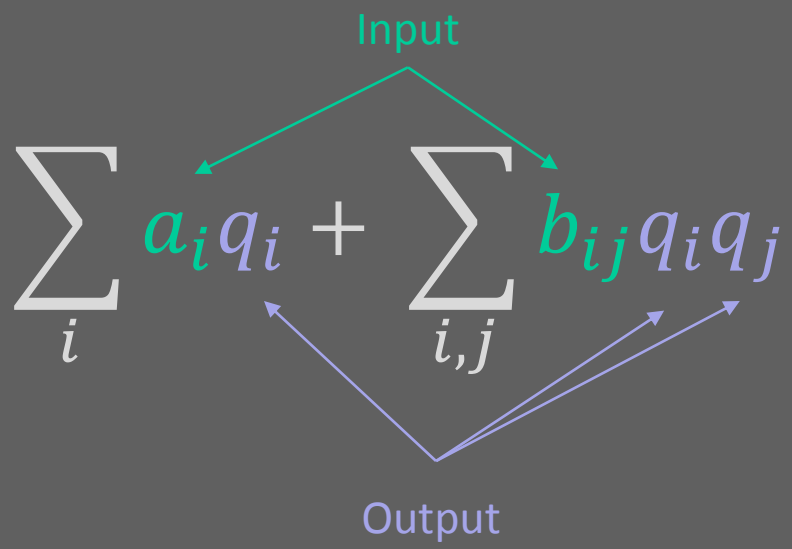
D-Wave chips consist of:

- magnetized niobium loops
- couplers



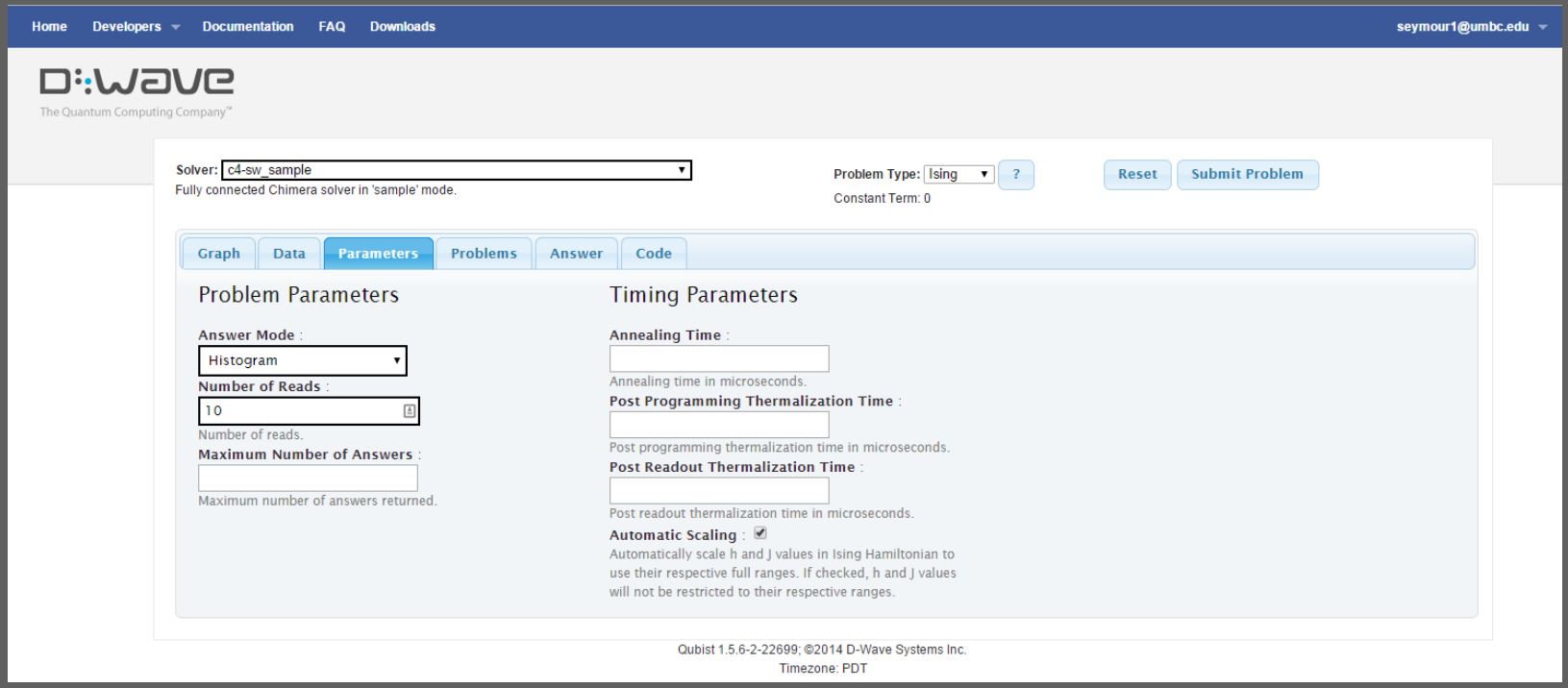


The D-Wave QUBO

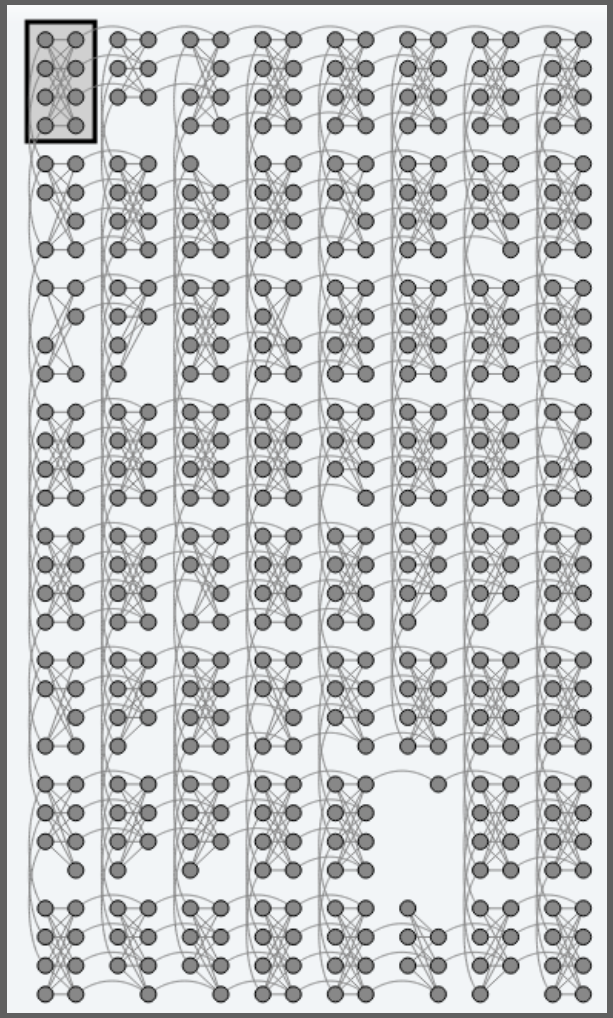


"Quadratic Unconstrained Binary Optimization"

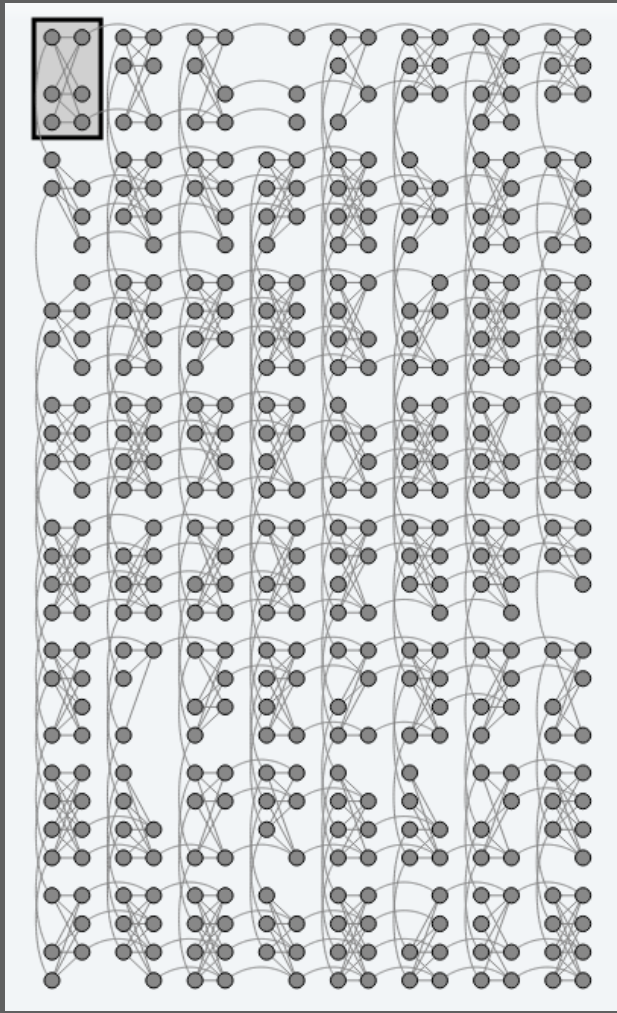
They’ve got a website. To do stuff on and stuff.



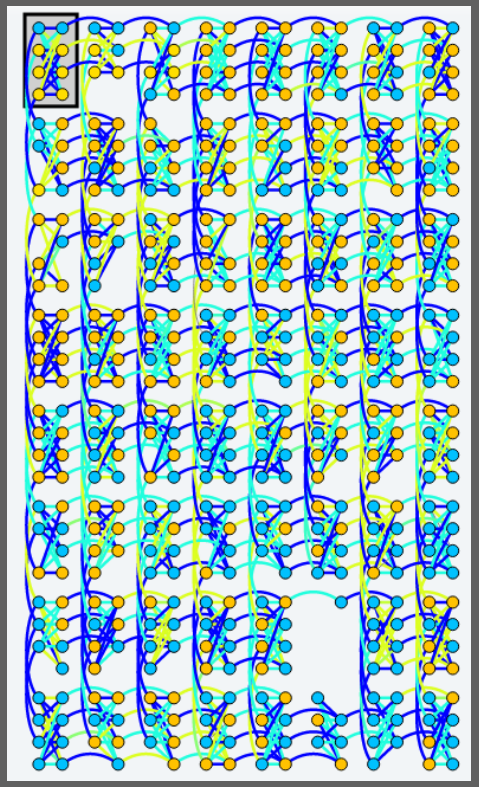
System 6



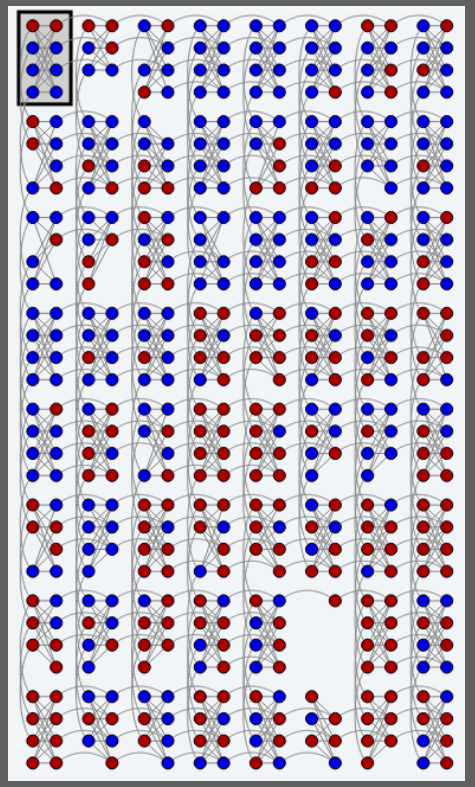
System 13



One D-Wave Run



Input



Output

Blackbox/QSage

- Software, developed by D-Wave
- Turns arbitrary problems into QUBOs
- Heuristic-based (problem is NP-Complete)
- Conversation between classical machine and D-Wave
  - Adds time from network latency

Blackbox Python Code

```
print "creating remote connection"
url = 'https://qubist.dwavesys.com/sapi/'
token = [redacted]
remote_connection = RemoteConnection(url, token)

print "starting BlackBox"
solver = remote_connection.get_solver('SYSTEM6')
obj = ObjectiveFunction()
blackbox_solver = BlackBoxSolver(solver)
blackbox_answer = blackbox_solver.solve(obj, num_vars)
blackbox_answer_bin = [int((item+1)/2) for item in blackbox_answer]
print "Best bitstring:",blackbox_answer_bin
```

So what can D-Wave machines do?

D-Wave claims applications: classification, protein-folding models, finding close-to-optimal solutions to NPC problems (e.g. Traveling Salesman)

Crash Course in Machine Learning
(At least what's relevant to this)

Boosting - using combinations of weak classifiers

- Consider 3 classifiers with 70% accuracy

All Correct: **0.7 * 0.7 * 0.7 = 0.3429**	**Two Correct:** **3 * 0.7 * 0.7 * 0.3 = 0.4409**
Two Wrong: 3 * 0.3 * 0.3 * 0.7 = 0.189	All Wrong: 0.3 * 0.3 * 0.3 = 0.027

- Majority vote can increase your accuracy to 0.7838! (Hint: add up the top row)
- Most boosting algorithms also allow weights for these classifiers.

http://mlwave.com/kaggle-ensembling-guide/

Loss

- Want to minimize:
  - Number of misclassifications
  - Complexity of the model

$$G(w) = \frac{1}{4}\sum_{s=1}^{S}(sign[\sum_{j=1}^{D} w_j F_j(x_s)] - y_s)^2 + \lambda \sum_{j=1}^{D} w_j$$

N-Grams

- Sliding window over text

$$DEADBEEF$$

N-Grams

- Sliding window over text

$$DEADBEEF$$

N-Grams

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N-Grams

- Sliding window over text

$$DEADBEEF$$

- Easy to generate
- Used before in malware with good results
- Easy to turn into weak classifiers
- Complex enough to compare classifiers

Building the “Quantum” Malware Classifier

QBoost

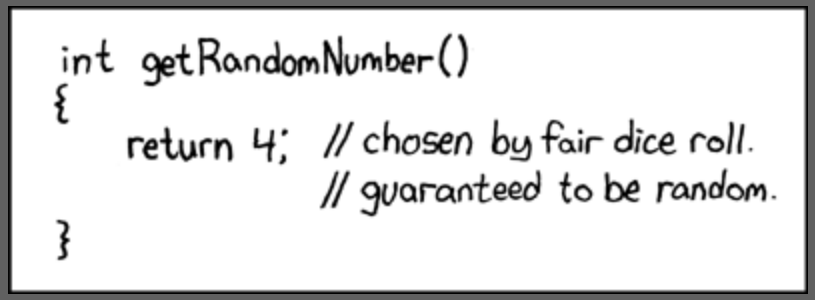
- Outperforms Adaboost
- Robust to label noise
  - Will generally still learn even if training data is mislabeled
  - Good for learning malware: ground truth is hard!
- Doesn’t scale to “Google-sized problems”
  - Blackbox supposedly can

Dataset used

- Plenty of malicious datasets to choose from
  - Vx Heaven, VirusShare, scraping the web
  - We used Vx Heaven (fairly standard but old)
- No standard for benign dataset
  - Problematic
  - Windows + Cygwin + Sourceforge
    - Don’t do this
    - No adware was used in the making of this classifier

(Classical) Preprocessing

- Resample corpus to be balanced
  - Side-effects: Less time to train, lose information



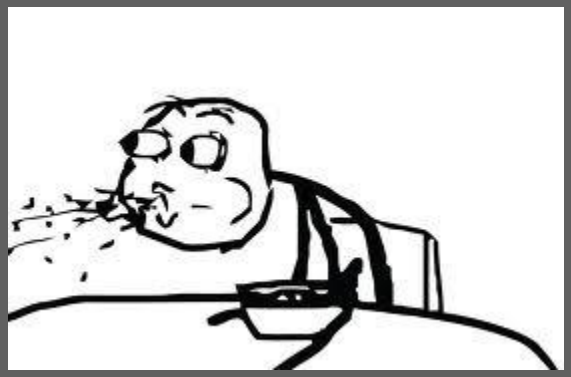
HTTP://XKCD.COM/221/

- Extract Features (3-gram bytes)

At first, our classifier was
no better than random chance

Next question: how long do we
need to let Blackbox run?

- Previous work says 30 minute timeout



- Pilot Experiment to find how long it should take
  - Even on small problems, it takes 10 minutes to find decent solutions
  - Larger problems require even more time

- Limited to 32 features
  - We used 16 malware and 16 benign n-grams
  - Implemented QBoost with 10-fold cross-validation using Blackbox
    - Both on D-Wave and using a simulator
- Compared to several models from WEKA
  - Adaboost
  - J48 Decision Tree
  - Random Forest

Results

Classifier	Cross-fold Accuracy	Average Time to Build (Seconds)
D-Wave	0.80	536.32
D-Wave Simulator	0.802	451.62
Adaboost	0.768	0.02
J48	0.796	0.03
RandomForest	0.814	0.05

Table 1: Cross-fold accuracy and time to build classifiers.

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Interesting Result 1: takes a LOT of time

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Interesting Result 2: Simulator > actual chip

What does it mean?

- Blackbox/D-Wave CAN learn a classifier
  - Probably a bad idea: significant overhead and must restrict problem substantially
  - We don’t know if this is due to Blackbox, the D-Wave chip, or some other issue
- General problem-solving on D-Wave is probably a bad idea
  - Really should’ve stuck with QBoost

- How much better is the next D-Wave chip?
- Embed directly onto chip, rather than use heuristics
- Better for another task?
  - e.g. feature preprocessing
- Machine Learning Standards for Malware Analysis

Thank you!

Questions?

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References

Original thesis: J. Seymour. Quantum classification of malware.

Dataset prep: J. Seymour and C. Nicholas. Overgeneralization in feature set selection for classification of malware.

Qboost: V. S. Denchev. Binary classification with adiabatic quantum optimization.

Qloss: V. S. Denchev. Robust Classification with Adiabatic Quantum Optimization.

References

Tutorial on Binary Classification using D-Wave: https://web.archive.org/web/20130927155053/http://www.dwavesys.com/en/dev-tutorial-qbc.html.

Evaluating Blackbox: C. C. McGeoch and C. Wang. Experimental evaluation of an adiabiatic quantum system for combinatorial optimization.