****

**BIRLA INSTITUTE OF TECHNOLOGY & SCIENCE, PILANI**

**WORK INTEGRATED LEARNING PROGRAMMES**

**COURSE HANDOUT**

**Part A: Content Design**

|  |  |
| --- | --- |
| **Course Title** | Software Architectures |
| **Course No(s)** | SE ZG651/SS ZG653 |
| **Credit Units** | 5 |
| **Course Author** | Nayan Khare |
| **Instructor –in-charge** | HARVINDER SINGH JABBAL |
| **Version No** | 1.4 |
| **Date** |  |

**Course Objectives:**

|  |  |
| --- | --- |
| **No** | **Course Objective** |
| **CO1** | To enable software engineers to architect software systems using industry best practices |
| **CO2** | To enable project managers to understand techniques of software architecture, and help them take appropriate decisions |
| **CO3** | To enable software professionals to take up research activities in the domain of software architecture |

**Learning Outcomes:**

|  |  |
| --- | --- |
| **No** | **Learning Outcome** |
| **LO1** | Ability to identify architecturally significant requirements and apply appropriate tactics to address them |
| **LO2** | Ability to determine appropriate architecture patterns for given requirements |
| **LO3** | Ability to document architecture that meets the needs of stakeholders |
| **LO4** | Ability to analyse architecture and determine its appropriateness given the requirement and determine risks |
| **LO5** | Awareness of best practices in design of cloud based applications, distributed applications and mobile applications |
| **LO6** | Awareness of new technologies and their architecture and understanding of situations when to use these technologies |
| **LO7** | Ability evaluate the cost and benefit of different architecture options to aid in decision making |

**Text Books:**

|  |  |
| --- | --- |
| T1 | Software Architecture in Practice, Third Edition, Len Bass, Paul Clements, Rick Kazman, Pearson 2013 ISBN:978-93-325-0230-7 |
| T2 | Essential Software Architecture, Second Edition, Ian Gorton, Springer 2011 ISBN:9783642191756 |

**Reference Material:**

|  |  |
| --- | --- |
| R1 | Software Modelling and Design, Hassan Gomaa, Cambridge University Press 2011, ISBN:9780521764148 |
| R2 | Microsoft Application Architecture Guide, Second Edition, Microsoft 2009, ISBN: 9780735627109 [Availability: Online Free] |
| R3 | Enterprise Architecture at Work: Modelling, Communication and Analysis, Third Edition, Marc Lankhorst et al., Springer 2013, ISBN:9783642296505 |
| R4 | Architecting for the cloud:  Developing Multi-tenant Applications for the Cloud on Microsoft Windows Azure, Third Edition, Microsoft 2012, ISBN:978-1-62114-023-8 [Availability: Online Free] |
| R5 | Architecting for the Cloud  Amazon Web Services – Architecting for the Cloud: Best Practices, January 2011, Jinesh Varia [Availability: Online Free] <https://media.amazonwebservices.com/AWS_Cloud_Best_Practices.pdf>  DZone’s Guide to Building and deploying applications on the cloud  https://dzone.com/guides/building-and-deploying-applications-on-the-cloud |
| R6 | Architecting for mobile   * <https://magora-systems.com/mobile-app-development-architecture/> * <https://www.intellectsoft.net/blog/mobile-app-architecture/> * <https://www.uxpin.com/studio/blog/successful-mobile-applications-ui-design-patterns/> * [https://www.smashingmagazine.com/2018/02/comprehensive-guide-to-mobile-app- design/](https://www.smashingmagazine.com/2018/02/comprehensive-guide-to-mobile-app-design/) * Architecting Mobile Solutions for the Enterprise – Dino Esposito, 2012, Microsoft Press, ISBN: 978-0-7356-6303-2 |
| R7 | Identifying Architecturally Significant Functional Requirement  Research paper by TCS – <https://www.researchgate.net/publication/278242211_What_You_Ask_is_What_You_Get_Understanding_Architecturally_Significant_Functional_Requirements> |
| R8 | ATAM case study – Rockwell Collins – CAAS – Common Avionics Architecture System  Video: <https://youtu.be/da9MHLeTwvY>  Product description: <https://www.rockwellcollins.com/Products_and_Services/Defense/Avionics/Integrated_Cockpit_Solutions/Common_Avionics_Architecture_System.aspx>  Rockwell Collins case study: <https://resources.sei.cmu.edu/asset_files/TechnicalNote/2003_004_001_14150.pdf> |
| R9 | ATAM case study: Battlefield Control System:  https://resources.sei.cm u.edu/asset\_files/TechnicalReport/2000\_005\_001\_13706.pdf |
| R10 | Serverless architecture:   * <https://docs.aws.amazon.com/lambda/latest/dg/welcome.html> * <https://docs.microsoft.com/en-us/azure/architecture/reference-architectures/serverless/web-app>   Container technology: <https://www.cio.com/article/2924995/what-are-containers-and-why-do-you-need-them.html>  Caching: <https://aws.amazon.com/caching/> , <https://aws.amazon.com/caching/implementation-considerations/>  Failure management in distributed systems:   * <https://docs.microsoft.com/en-us/azure/architecture/guide/design-principles/self-healing> * <https://dzone.com/articles/microservices-in-practice-1> |
| R11 | Technology topics  Technologies: <https://docs.microsoft.com/en-us/azure/architecture/>  NoSQL databases  [https://www.dataversity.net/a-brief-history-of-non-relational-databases/#](https://www.dataversity.net/a-brief-history-of-non-relational-databases/)  <https://www.couchbase.com/resources/why-nosql>  <https://www.thoughtworks.com/insights/blog/nosql-databases-overview>  Big data analytics  Data mining & analytics: <https://www.educba.com/data-mining-vs-data-analysis/>  Technologies: <https://www.edureka.co/blog/top-big-data-technologies/>  Tools: <https://www.guru99.com/big-data-analytics-tools.html>  Use cases: <https://www.datamation.com/big-data/big-data-use-cases.html>  Case studies: <https://data-flair.training/blogs/big-data-case-studies/>  <https://businessesgrow.com/2016/12/06/big-data-case-studies/>  Hadoop  <https://www.mssqltips.com/sqlserverauthor/77/dattatrey-sindol/>  <https://en.wikipedia.org/wiki/Apache_Hadoop>  <https://mapr.com/products/apache-hadoop/>  <https://www.sas.com/en_in/insights/big-data/hadoop.html>  Real time analytics  <https://www.sisense.com/glossary/real-time-analytics/>  <https://searchcustomerexperience.techtarget.com/definition/real-time-analytics>  <https://www.scnsoft.com/blog/real-time-big-data-analytics-comprehensive-guide>  Spark  <https://spark.apache.org/streaming/>  <https://databricks.com/glossary/what-is-spark-streaming>  Use cases: <https://www.qubole.com/blog/apache-spark-use-cases/>  Machine learning  <https://docs.microsoft.com/en-us/azure/architecture/data-guide/big-data/machine-learning-at-scale>  Primer: <https://www.sas.com/content/dam/SAS/en_us/doc/whitepaper1/machine-learning-primer-108796.pdf>  Steps: <https://towardsdatascience.com/6-important-steps-to-build-a-machine-learning-system-d75e3b83686>  Blockchain  Introduction: <https://www.pwc.co.uk/financial-services/fintech/assets/blockchain-an-intro.pdf>  Blockchain at Maersk: <https://www.computerworld.com/article/3298522/ibm-maersk-launch-blockchain-based-shipping-platform-with-94-early-adopters.html>  Security  OpenId: <https://en.wikipedia.org/wiki/OpenID>  OAuth: <https://tools.ietf.org/html/draft-ietf-oauth-use-cases-01#section-2.1>  <https://www.csoonline.com/article/3216404/what-is-oauth-how-the-open-authorization-framework-works.html>  De-militarized zone: <https://searchsecurity.techtarget.com/definition/DMZ>  Firewall:  <https://www.cio.com.au/article/365101/top_seven_firewall_capabilities_effective_application_control/>  [https://www.fortinet.com/products/next-generation-firewall.html#services](https://www.fortinet.com/products/next-generation-firewall.html)  <https://www.securedgenetworks.com/blog/11-Features-to-Look-for-in-Your-Next-Generation-Firewall>  LDAP: <https://stackoverflow.com/questions/239385/what-is-ldap-used-for>  Integration strategies:  Book ‘Enterprise Integration Patterns’ - Gregor Hohpe and Bobby Woolf  IoT  <https://docs.microsoft.com/en-us/azure/architecture/reference-architectures/iot/> |
| R12 | Technology trends:  <https://www.thoughtworks.com/radar>  <https://www.infoq.com/>  <https://www.developertoarchitect.com/>  Micro-frontends: https://martinfowler.com/articles/micro-frontends.html |
| R13 | Transitioning from Developer to Architect: <https://www.youtube.com/watch?v=JV8HNsFWHD4> |
| R14 | Case studies  Architecture patterns – Case studies   * SoA at CIGNA * SaleForce.com * SoA at TripAdvisor * Micro-Services at Danske Bank     Architecture evaluation and revision – Case study    Scaling, caching, reliability case study: Netflix  <http://highscalability.com/blog/2017/12/11/netflix-what-happens-when-you-press-play.html> |
| R15 | Microservices in practice: <https://dzone.com/articles/microservices-in-practice-1> |
| R16 | Tactics to address different quality attributes: <https://docs.microsoft.com/en-us/azure/architecture/patterns/category/availability> |

**Modular Content structure**

|  |  |
| --- | --- |
| **Module No** | **List of Topic Title** |
| M1 | Introduction to Software Architecture   * What is Software Architecture? * Definitions of Software Architecture * Architecture Structure and Patterns * Good architecture * Importance of Software architecture * Contexts of Software architecture * Architecture competence |
| M2 | Software Quality Attributes   * Understanding Quality Attributes * Interoperability * Testability * Usability * Performance * Scalability * Modifiability * Security * Availability * Integration * Other Quality Attributes * Design Trade-Offs |
| M3 | Capturing Architecturally Significant Requirements   * Challenges in identifying ASRs * Quality attribute Workshop   + Understanding business goals from Sponsors   + Identifying architectural drivers   + Understanding Scenarios for each architectural driver via brainstorming with stakeholders   + Prioritizing scenarios   + Building a Utility tree   Architecture design   * Design strategy * Steps of Attribute-Driven design * Architecting in Agile projects |
| M4 | Documenting Software Architecture   * Importance of architecture documentation * Architecture Views * Quality attribute views – Security view, Communication view, Reliability view * Combining Views * *Philippe Kruchten’s* **4+1 view** * Documentation Package |
| M5 | Layered architecture: Guidelines for different layers   * Presentation * Business * Data Layer * Service   Architecture evaluation (ATAM)   * Factors for evaluation * Trade off analysis * Evaluation method   Architecture Conformance techniques during implementation  Architecture & Testing  Architecture Reconstruction   * Raw view extraction * View fusion * Finding violations |
| M6 | Architectural patterns   * Layered * MVC * Publish-subscribe * Pipe & Filter * Service Oriented Architecture and Micro-services |
| M7 | Architectural patterns   * Broker * Client server * Peer-to-Peer * Shared data * Map-reduce * Multi-tier |
| M8 | Integration strategies  File transfer, Messaging, RPC, WebSockets, API Gateways  Architecting for Cloud   * Benefits of Cloud based approach * Developing Multi-tenant Applications for the Cloud * Amazon Web Services tools * Trends in Cloud app development – languages, DB, Micro-services, CI / CD   Technologies   * Distributed Cache * Containers * Serverless architecture   Failure management   * CAP theorem * Failure management in distributed systems |
| M9.1 | Architecting for Mobile   * Types of mobile applications: native, cross platform, web app * Design considerations * Android Application components * Patterns in Mobile Application   + Store locally, sync later   + Responsive design   + UI design patterns |
| M9.2 | New technologies & their architecture  Use cases and architecture of:   * Big data   + NoSQL Databases   + Hadoop   + MapReduce   + Real-time analytics * Artificial intelligence & Machine Learning * Block Chain * IoT * Security: AuthID, OAuth |
| M10.1 | Economic analysis of architectures   * Decision-making context * Basis for economic analysis * Cost Benefit Analysis Method |
| M10.2 | Recent developments and Emerging trends   * WebAssembly * Service mesh * Edge computing |

**Session plan**

|  |  |  |  |
| --- | --- | --- | --- |
| **Session** | **List of Topic Title** | **Reference** | **Module** |
| 1 | Introduction to Software Architecture   * What is Software Architecture? * Definitions of Software Architecture * Architecture Structure and Patterns * Good architecture * Importance of Software architecture * Contexts of Software architecture * Architecture competence | T1 - 01, 02, 03, 24 | M1 |
| 2 | Software Quality Attributes   * Understanding Quality Attributes * Availability * Performance * Usability * Security * Modifiability | T1 - 04, 05, 06, 07, 08, 09, 10, 11, 12  R16 | M2 |
| 3 | Software Quality Attributes (cont.)   * Interoperability * Testability * Scalability * Integration * Other Quality Attributes   Design Trade-Offs | R16 | M2 |
| 4 | Capturing Architecturally Significant Requirements   * Challenges in identifying ASRs * Quality attribute Workshop   + Understanding business goals from Sponsors   + Identifying architectural drivers   + Understanding Scenarios for each architectural driver via brainstorming with stakeholders   + Prioritizing scenarios   + Building a Utility tree | T1 - 15, 16, 17  R7 | M3 |
| 5 | Architecture design   * Design strategy * Steps of Attribute-Driven design * Architecting in Agile projects | T1 - 15, 16, 17  R7 | M3 |
| 6 | Documenting Software Architecture   * Importance of architecture documentation * Architecture Views * Quality attribute views – Security view, Communication view, Reliability view * Combining Views * *Philippe Kruchten’s* **4+1 view** * Documentation Package | T1 – 18 | M4 |
| 7 | Layered architecture: Guidelines for different layers   * Presentation * Business * Data Layer * Service   Architecture evaluation (ATAM)   * Factors for evaluation * Trade off analysis * Evaluation method | R2  T1 – 21  R8  R9 | M5 |
| 8 | Architecture Conformance techniques during implementation  Architecture & Testing  Architecture Reconstruction   * Raw view extraction * View fusion * Finding violations | T1 - 20  T1 - 19  T1 – 20 | M5 |
| 9 | Architectural patterns   * Layered * MVC * Publish-subscribe * Pipe & Filter * Service Oriented Architecture and Micro-services | T1  R14 | M6 |
| 10 | Architectural patterns (cont.)   * Broker * Client server * Peer-to-Peer * Shared data * Map-reduce * Multi-tier | T1  R14 | M7 |
| 11 | Integration strategies  File transfer, Messaging, RPC, WebSockets, API Gateways  Architecting for Cloud   * Benefits of Cloud based approach * Developing Multi-tenant Applications for the Cloud * Amazon Web Services tools * Trends in Cloud app development – languages, DB, Micro-services, CI / CD | T1  R4  R5 | M8 |
| 12 | Technologies   * Distributed Cache * Containers * Server-less architecture   Failure management   * CAP theorem * Failure management in distributed systems | R10  R10 | M8 |
| 13 | Architecting for Mobile   * Types of mobile applications: native, cross platform, web app * Design considerations * Android Application components * Patterns in Mobile Application   + Store locally, sync later   + Responsive design   + UI design patterns | R6 | M9.1 |
| 14 | New technologies & their architecture  Use cases and architecture of:   * Big data   + NoSQL Databases   + Hadoop   + MapReduce   + Real-time analytics * Artificial intelligence & Machine Learning * Block Chain * IoT * Security: AuthID, OAuth | R11  R12 | M9.2 |
| 15 | Economic analysis of architectures   * Decision-making context * Basis for economic analysis * Cost Benefit Analysis Method | T1 | M10 |
| 16 | Recent developments and Emerging trends   * WebAssembly * Service mesh * Edge computing | R12 | M10 |

Mid sem exam syllabus: Modules 1 to 5

Compre exam syllabus: Modules 1 to 10

**Contact sessions**:

The contact session is expected to cover:

* Key concepts in the module
* Examples / case studies
* Experience sharing from participants
* Exercises

Students are expected to go through the reference material.

Students may be given home work at the end of each contact session.

**Sample Assignments:**

**Assignment #1** (5% weight)

**Objective:** To get familiar with the software architecture basics.

**Activity:**

1. Choose an existing system from your workplace
2. Understand the purpose (goal) of the system & its key requirements
3. Study the architecture and understand the tactics used

**Document** your work in the following format in PPT:

1. Purpose of the system (Goal)
2. Key requirements of the system – functional & non-functional
3. Utility tree of Architecturally Significant Requirements (ASR)
4. Tactics used to achieve the top 5 ASRs
5. Software Architecture diagram – Context diagram, Module decomposition, Component & Connection diagram, Deployment diagram
6. Description of how the system works
7. Key learnings (one slide per participant)

**Assignment #2** (10% weight)

**Objective:** To gain experience in architecting real life applications in domains such as Retail, Transportation, Healthcare, Hospitality, etc. Example systems: Swiggy, Uber, an IoT system to monitor health of industrial air conditioners.

**Activity**

1. Identify top 3 Architecturally Significant Requirements (ASRs) and write them in the form of a Utility tree. Why are these architecturally significant?
2. Describe in detail, the tactics you recommend for each ASR. For example, if caching is a tactic you recommend, please mention what you will cache, what tool you would use, how it will work, etc.
3. Draw 2 software architecture diagrams – component & connection view and deployment view – to understand how the system works.
4. Indicate important messages between components by labelling the connections in the C&C view. Also indicate the communication method used.
5. Draw sequence diagram for one major scenario (use case). Mention the scenario.
6. State the architecture patterns used. Explain, where in the architecture, these patterns have been used.
7. What did you learn by doing this assignment? Mention 3 key learnings. One slide per person.

**Evaluation criteria:**

1. Easy-to-understand diagrams
2. Clarity of description
3. Correctness of work products

**Evaluation Components**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **No** | **Name** | **Type** | **Duration** | **Weight** | **Day, Date, Session, Time** |
| EC-1 | Quiz-I | Online |  | 5% | February 17-27, 2025 |
|  | Quiz-II | Online |  | 5% | April 1-10, 2025 |
|  | Quiz-III | Online |  | 5% | May 1-10, 2025 |
|  | Assignment I | Online |  | 5% | TBA |
|  | Assignment-II | Online |  | 10% | Individual Submission  TBA  Group Discussion  TBA |
| EC-2 | Mid-Semester Exam | Closed Book | 2 Hours | 30% | 22/03/2025 (FN) |
| EC-3 | Comprehensive Exam | Open Book | 2 ½ Hours | 40% | 24/05/2025 (FN) |

***Note*** *- Evaluation components can be tailored depending on the proposed model.*

## Syllabus for exams:

* Syllabus for Mid-Semester exam (Closed Book): Modules 1-5
* Syllabus for Comprehensive exam (Open Book): Modules 6-10

**Evaluation Guidelines:**

1. For Closed Book tests: No books or reference material of any kind will be permitted. Laptops/Mobiles of any kind are not allowed. Exchange of any material is not allowed.
2. For Open Book exams: Use of prescribed and reference text books, in original (not photocopies) is permitted. Class notes/slides as reference material in filed or bound form is permitted. However, loose sheets of paper will not be allowed. Use of calculators is permitted in all exams. Laptops/Mobiles of any kind are not allowed. Exchange of any material is not allowed.
3. If a student is unable to appear for the Regular Test/Exam due to genuine exigencies, the student should follow the procedure to apply for the Make-Up Test/Exam. The genuineness of the reason for absence in the Regular Exam shall be assessed prior to giving permission to appear for the Make-up Exam. Make-Up Test/Exam will be conducted only at selected exam centres on the dates to be announced later.

It shall be the responsibility of the individual student to be regular in maintaining the self-study schedule as given in the course handout, attend the lectures, and take all the prescribed evaluation components such as Assignment/Quiz, Mid-Semester Test and Comprehensive Exam according to the evaluation scheme provided in the handout.